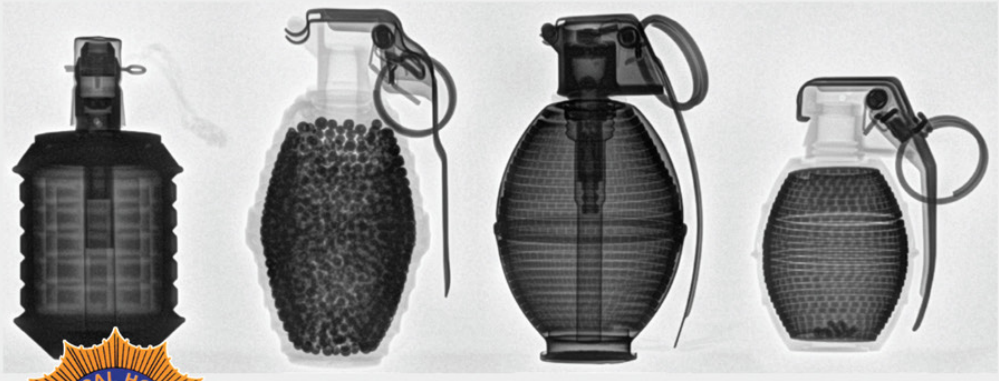
SECOND EDITION

Practical Military Ordnance Identification

Tom Gersbeck, MFS
Daniel Evers



Practical Aspects of Criminal and Forensic Investigations

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Second Edition

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Cover: Foreground: X-ray of hand grenades, left to right, Japanese Type 97 with serrated cast body, former-Yugoslavian M85 with plastic body concealing fragmentation layer of ball bearings, U.S. M26 with coiled-spring fragmentation liner covered with smooth sheet-metal, and Belgian M72 with plastic body concealing fragmentation layer of bearings.

Background photographs are Russian TM57 & TMN46 anti-tank landmines, and MON100 anti-personnel landmines staged for disposal. (Author's photograph, x-ray courtesy of Kristin Lejeune.)

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This book is dedicated to the bomb technicians who have paid the ultimate price, and those risking it all every day.

There are memorials around the world for bomb technicians, including two in the United States. The military EOD Memorial on Eglin Air Force Base carries the names of 338 EOD technicians killed while conducting EOD operations. The Public Safety Bomb Technician Memorial at HDS on Redstone Arsenal in Alabama carries the names of 15 bomb technicians killed in the line of duty.

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Series Editor

The Series Editor for *Practical Aspects of Criminal and Forensic Investigations* is Lieutenant Commander (retired) Vernon J. Geberth, New York City Police Department, who was the commanding officer of the Bronx Homicide Task Force, which handled more than 400 homicides a year. Geberth has been president of P.H.I. Investigative Consultants, Inc., since 1987. He has more than 47 years of law enforcement experience and has conducted homicide investigation seminars for more than 74,000 attendees from more than 8,000 law enforcement agencies.

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He created, edited, and designed this series of more than 65 publications to provide contemporary, comprehensive, and pragmatic information to the practitioner involved in criminal and forensic investigations by authors who are nationally recognized experts in their respective fields.

He welcomes the opportunity to review new proposals for books covering any area of criminal and forensic investigation and may be reached through his email: vernongeberth@practicalhomicide.com.

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Foreword

The study, research, and investigation of military ordnance is both exciting and fascinating. However, when one crosses the threshold from the study of ordnance to its physical recovery, the element of danger becomes dominant. The recovery of ordnance requires not only a certain temperament but also a unique set of skills. Military, law enforcement, and contracted civilian personnel whose task is to remove and neutralize discovered ordnance must rely on their ability to correctly identify the munitions. Their lives and the lives of others depend upon it.

In this updated volume, Tom Gersbeck provides not only the detailed information for the correct identification of ordnance, but also focuses on the all-important processes for safe investigation and recovery. Mr. Gersbeck has decades of ordnance experience in both military and academic settings, making him, in my judgment the very best in this field.

The practitioner will find in this volume the most precise presentation of military ordnance in print today. The author presents detailed data on a wide range of munitions, covering land, air, and subsurface ordnance. End users of this text will find helpful figures and photographs, as well as appendices full of technical data. Most importantly, the processes outlined in each chapter for the safe approach and identification of ordnance provide life-preserving techniques for the practitioner.

We live in a dangerous world, and much of that danger is man-made. Given the amount of military ordnance which remains undiscovered, this text will be recognized as one of the most important contributions to the field of munition recovery and neutralization. We are indeed fortunate to have the expertise of Tom Gersbeck in making our world a safer place in which to live.

James D. Hess, EdD

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Preface

Military history has always fascinated me, and studying campaigns and engagements convinced me that ordnance is the primary tool of success or failure. In this second edition of *Practical Military Ordnance Identification*, my objective has been to provide pertinent, multidisciplinary information covering many ordnance-related topics. Each chapter and appendix has been expanded, a chapter on pre-1900 ordnance, appendices on missiles, rockets, and pre-1900 projectile diameters have been added. Additionally, the pull-out logic-tree in the back cover has been expanded to cover these updates. What is not covered are render safe procedure (RSPs) or other classified topics.

For centuries, many of the brightest engineers, chemists, physicists, tacticians, mathematicians, and those from other professional fields developed weapons and ordnance for their countries' military. Designed to address a tactical problem, ordnance constitutes the tools-of-the-trade for waging war. As such, countries capable of maintaining a tactical and technical advantage enjoy significant political advantage over those who cannot and are more likely to survive.

The history of Constantinople offers an example where failing to maintain such an advantage led to its downfall. Armed with the highly classified "Greek fire," Constantinople prevailed in more than 20 invasions spanning eight centuries. In 1453, the city was attacked by forces deploying a new technology, black-powder-fired cannon. Literature on the battle mentions numerous cannons, the largest having a 30-inch (762mm) bore diameter. When loaded, this massive gun was capable of projecting a 1,500lb (680kg) spherical stone over a mile (1.61km) smashing holes in the city's protective wall. Consequently, Constantinople capitulated after weeks of fighting.

The actual hazards associated with military ordnance remain something of a mystery to all but a few specializing in this area. Ordnance design and construction is a scientific and engineering endeavor. When a munition of unknown origin is discovered and inspected, a largely subjective deductive process is applied to identify it. This process, broken into seven steps focuses largely on the elimination of what the item is not, before progressing to more specific identification techniques. For those responsible for protecting the public, it is essential to understand the threats posed by these items.

Ordnance is commonly recovered in communities around the world. To cover a tremendous amount of information and dispel some of the mystery

associated with ordnance, this book focuses on identifiable construction and design characteristics. Though far from absolute, these characteristics offer a measure of constants and follow the classification system used by the military. Understanding design characteristics and terminology when working to identify an unknown munition is the formula to success. It is not a magic bullet, but rather a foundation on which to begin the perpetual learning curve associated with ordnance.

Common sources for unidentified ordnance recovered in public areas include:

- War souvenirs, including Explosive Remnants of War (ERW), or Unexploded Ordnance (UXO).
- People working in ordnance research or manufacturing.
- Ordnance burial sites, which was a common means of disposal until the 1960s.
- Development of land formerly used for military training.
- Ordnance disposed of at sea or in waterways recovered by fishermen or washed ashore during storms.
- Ordnance stolen from the military. There is a cottage industry, referred to as "scrapping." People sneak onto impact areas to recover aluminum, copper, and other materials. Ordnance is also taken, accidentally or purposefully to sell or use in conjunction with criminal activities.
- Ordnance recovered from historic battlefields and shipwrecks.
- Munitions illegally transported into the United States for criminal purposes.

This book is written for public safety bomb technicians, SWAT personnel, explosives detection canine handlers, emergency management personnel, beach and park patrol units, forensic laboratory personnel, Evidence Response Teams, UXO technicians, deminers, Coast Guard personnel, archeologists, all military personnel and other first responders, as well as history enthusiasts, museum employees, and those studying in these fields. The goal of this book is to offer these professionals a means of identifying a potential threat as well as how to accurately articulate critical information to people in a position to assist in safely resolving a potentially dangerous situation. The deductive process outlined in this book was designed with these professionals in mind.

Acknowledgments

This book would not have been possible without the assistance of many people whom I am deeply indebted to for their help. Thank you to the Marine Corps Camp Pendleton, Camp Lejeune, and Twenty-nine Palms EOD teams for allowing me to photograph ordnance in their collections.

To Daniel Evers, I want to express my gratitude as your ordnance knowledge and ability to research complex questions ensured the technical accuracy of this book. I am deeply indebted to Larry Babits, PhD for providing technical and academic guidance throughout this process, and Jim Hess, EdD for reading the completed manuscript, providing feedback, and authoring the Foreword. Ed Bender for your unparalleled guidance on the chemistry of energetics, ensuring the accuracy and functionality of this book, most notably in Chapter 1 and Appendix D. And John Ismay for the tremendous insight provided on the history of submunitions.

I am exceptionally grateful to John Frucci, PhD for bringing me to Oklahoma State University to turn the original version of this book into a successful graduate level course. However, the primary influences on my life and this book were, and continue to be, provided by my parents, Edward and Ellen Gersbeck, and my wife, Laura, who continually motivated me to finish this work.

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About the Author and Technical Researcher

Tom Gersbeck served as an Explosive Ordnance Disposal (EOD) technician in the U.S. Marine Corps, retiring in 2001 as a Chief Warrant Officer. He then served seven years with the Federal Air Marshal Service (FAMS) as an explosives security specialist before deploying as an independent contractor. Deployments include two tours in Afghan CEXC facilities and one tour as project manager of Task Force Paladin's C-IED mobile training teams operating throughout the country. Deployments in support of Department of State include serving as an EOD team lead in Iraq, advising the Tanzanian Peoples Defense Force after the Gongo La Mboto disaster (Feb 2011) and training deminers with Golden West Humanitarian Foundation in Cambodia.

Today, Tom is a full-time member of the graduate faculty for Oklahoma State University's School of Forensic Sciences, Arson-Explosives, Firearms & Toolmarks Investigation (AEFTI) program. He holds a master of forensic sciences (MFS) degree, is an active member of the International Association of Bomb Technicians and Investigators (IABTI), is a Fellow in the American Academy of Forensic Sciences (AAFS), and continues to work in his field.

Technical Researcher

Daniel Evers joined the Marine Corps in 2003 and currently serves as an Explosive Ordnance Disposal (EOD) technician. While stationed in California, North Carolina, and Japan, Daniel deployed to Iraq, Afghanistan, Romania, Latvia, and Georgia in support of combat operations, responding to IED- and ordnance-related calls for assistance, and training personnel responsible for EOD-related work. However, Daniel's advanced technical ordnance knowledge and research abilities were developed during countless inerting and disassembling operations on ordnance ranging from the mid-1800s to the complex guided missile systems of today.

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Explosives and Hazardous Compounds Used in Ordnance

1

Try to learn something about everything and everything about something
Thomas Henry Huxley

Introduction

Understanding how military ordnance operates and functions requires a basic understanding of energetic and other hazardous compounds. Explosives, propellants, pyrotechnics, pyrophorics, and other reactive substances are used extensively in ordnance to provide different effects. In addition to propelling or fragmenting a munition, these materials are used to arm fuzing systems, deploy payloads, illuminate the night, and track trajectories; as well as energize power sources for fuzing, steerable fins, guidance systems, and other functional purposes.

The military has unique requirements due to the extreme environments in which ordnance is used. For example, in the United States, all materials required to make an explosive must be available in the lower 48 states, which ensures availability and deters reliance on foreign sources. Other unique considerations include bullet impact sensitivity, reactivity with other materials, hygroscopicity, and long-term stability in storage.

This chapter introduces the basic principles and unique attributes of energetic and other hazardous materials used in military ordnance. It is divided into eight sections:

- Terms and Definitions
- Introduction to High Explosives
- High Explosives—Groups
- High Explosives—Configurations and Effects
- Introduction to Low Explosives and Propellants
- Low Explosives and Propellants—Groups
- Low Explosives and Propellants—Effects and Configurations
- Pyrotechnics, Incendiaries, Pyrophorics, and Smoke Producing Compounds

Terms and Definitions

The definitions provided here are fundamental considerations associated with energetic and hazardous compounds. Additional information on terms, definitions, and abbreviations may be found in Appendices B, C, D, E, and the Bibliography.

Hygroscopicity: The tendency of a material to absorb moisture from the air. The introduction of moisture may affect the sensitivity or stability characteristics of an energetic material.

Reactivity: Energetic materials may chemically react and create other substances when in close proximity to different materials.

Sensitivity: How an energetic material reacts to heat, shock, or friction.

Stability: All explosives decompose over time. Temperature, moisture, pressure, and time contribute to decomposition and stability of energetic materials. Compounds that decompose slowly are sought for military applications.

Toxicity: Most energetics are toxic to some degree and present inhalation, absorption, and ingestion hazards.

Introduction to High Explosives

Much of the information contained in this text focuses on chemical and mechanical explosions. A few definitions relevant to high explosives are provided below and additional definitions and abbreviations are available in Appendices B, C, D, E, and the Bibliography.

Explosion: A sudden, violent release of energy.

Detonation: A chemical reaction that propagates a self-sustaining shockwave that proceeds the reaction zone through the unreacted material at greater than the speed of sound.

High Explosive (HE): A chemical composition capable of detonating when properly configured and initiated. The defining factor between a detonation and explosion; is speed, measured as the velocity of detonation (VOD). It is important to note that all explosives explode, but only high explosives can detonate.

Velocity of Detonation (VOD): The speed at which a self-sustaining shockwave propagates through an explosive composition at a velocity greater than the speed of sound in that material. Factors affecting the VOD include; explosives chemistry, density, temperature, geometry, purity, and method of initiation. VOD is measured in feet per second (fps) or meters per second (mps).

High-Explosive Performance Characteristics

Common terms associated with high-explosive-filled munitions:

High-Order Detonation: When the high explosive charge performs correctly, the munition "high ordered."

Brisance: Determined by the detonation pressures generated, brisance addresses the shattering capability of a high explosive. An explosive with a fast VOD is more "brisant" then one with a slower VOD.

Sympathetic Detonation: When the detonation of one munition is caused by the explosive shockwave from another in close proximity.

Low-Order Detonation: When the high explosive charge partially detonates or does so at an insufficient velocity. Possible causes include, poor chemistry or manufacturing techniques, contamination, insufficient initiation, or explosives deteriorating over time. A munition low-ordering, results in additional hazards such as, damaged and burned explosives and munition components littering an area.

High Explosives—Groups

High explosives are broken into three groups: primary, secondary, and main charge explosives. For a munition to function as designed, explosive components from all three groups are arranged in order of decreasing sensitivity. Referred to as an explosive train, this configuration allows the incorporation of fail-safes in ordnance designs (Figure 1.1).

Every country utilizes a variety of high explosives in ordnance. Due to the vast number of possible compositions, a few examples of explosives used in ordnance by many countries are listed below. However, in literature there is much conflicting information, the VODs of pure explosives listed here are cited from *Explosives* 6th Edition (Meyer, Kohler, Homburg, 2007). VODs of blended and other explosives are from various sources and listed as "approximately" due to variation dependent upon mixture ratios. Additional information on explosives from each group is available in Appendices D, E, and the Bibliography.

Primary Explosives: Are the least powerful, but most sensitive of the three groups.

Characteristics include:

1. Will not burn, but will detonate, and are very sensitive to initiation from the heat of an electrical source or flame, the shock of mechanical impact, or the friction of two surfaces rubbing together.

2. Provide enough energy to reliably initiate less sensitive secondary explosives.
3. Used in primers, detonators, initiators, leads, relays, and other fuzing components.

Examples:

Lead Azide: Commonly used in modern ordnance.

- Color ranges from white-buff to gray.
- VOD of pure lead azide 14,800 fps (4,500 mps) @3.8g/cm^3.
- Moderately hygroscopic. Reacts with copper to form extremely sensitive cupric azide. For this reason, it is usually loaded in an aluminum housing.
- Other names include: Lead Hydronitride (U.S.), Azoture de Plomb (France), Bleiazid (Germany), Chikka Namari (Japan), and Acido di Pimbo (Italy).

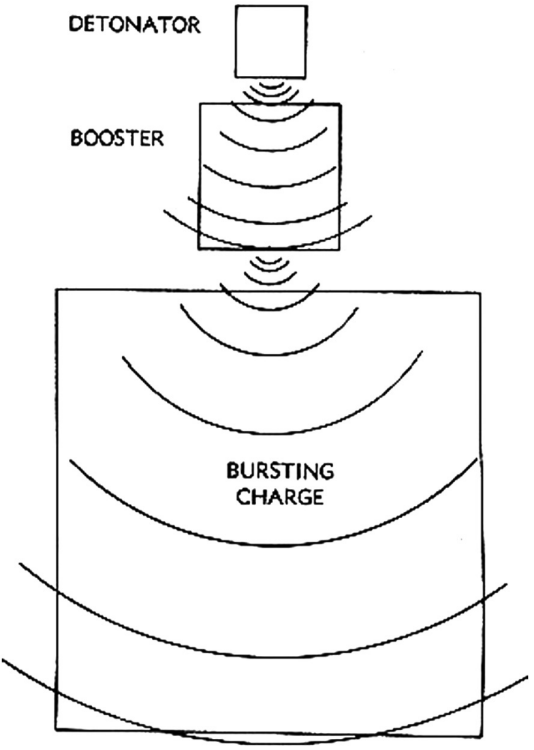

Figure 1.1 Basic high explosive (HE) firing train. Depending on design and explosives used, the booster in the center may not be required. (From U.S. Military TM.)

Lead Styphnate: In use since WWI.

- Color ranges from yellow, orange to reddish brown.
- VOD, 17,000 fps (5,200 mps) @2.9g/cm^3.
- Slightly hygroscopic.
- Other names include: Trinitrorescorcinate de Plomb (France).

Note: The initiating efficiency of lead styphnate is poor but is easily initiated by flame. Lead azide is more difficult to initiate by flame, but a good initiator. Because of the ease of initiation of lead styphnate and the initiating efficiency of lead azide, a combination of the two has been used in blasting caps and detonators since 1920.

Mercury Fulminate: Widely used until replaced by lead azide and lead styphnate.

- Color ranges from white, light-yellow-brown, or gray.
- VOD, 16,400 fps (5,000 mps) @3.3g/cm^3.
- Non-hygroscopic. Reacts with aluminum, magnesium, copper, zinc, and brass.
- Other names include: Fulminate of Mercury (U.S.), Fulminate de Mercure (France), Knallquecksilber (Germany), Fulminato di Mercurio (Italy), Rtutnyy ful'minat (Russia), and Raisanuigin (Japan).

Secondary Explosives: Are usually mixed to make main charge explosives. Characteristics include:

1. Not as sensitive to heat, shock, or friction as primaries, and usually burn when unconfined. As a dust they are susceptible to exploding if exposed to static discharge.
2. Provide enough energy to reliably initiate main charge explosives.
3. Used between primary and main charge explosives as boosters, leads, relays, and other fuzing components.

Examples:

TNT: One of the most common explosives used in ordnance. Discovered in 1863, TNT was first used in ordnance by Germany in 1902. The energetic properties of TNT are the basic standard when characterizing other explosives where TNT = 1.

- Color ranges from light brown, to light-yellow.
- VOD, 22,600 fps (6,900 mps) @1.60g/cm^3.
- Non-hygroscopic. Reacts with ammonia, sodium hydroxide, sodium carbonate, and other alkalies to form extremely sensitive compounds.

- Other names include: Trinitrotoluene (chemical name), Trotyl (UK), Tolite (France), Fullpulver 02, and Sprengmunition 02 (Germany), Chakatusuyaku (Japan), Tritolo (Italy).

Note: Main charge explosives containing a high percentage of TNT include: Amatol, Ammonal, Ammonite, Baratol, Baronal, Boracitol, Cheddite, Composition B, Cyclotol, Ednatol, H-6, Hexanite, HBX, Octol, Picratol, Plumbatol, PTX, Tetrytol, Torpex, and Tritonal to name a few.

Tetryl: Invented in 1877, Tetryl is expensive to make and was eventually replaced by RDX and HMX.

- Color is yellow, but when graphite is added, it turns gray.
- VOD, approximately 24,800 fps (7,570 mps) @1.71g/cm^3.
- Slightly hygroscopic. Reacts slightly with zinc, iron, and brass.
- Other names include: 2,4,6-trinitrophenylmethylnitramine (chemical name), Composition Exploding "CE" (UK), and Tetra (Germany).

RDX: Very common in ordnance, it is almost 50% more brisant and 75% more powerful than TNT. Discovered in 1899, RDX was not used extensively until WWII.

- Color is white.
- VOD, 24,000 fps (7,300 mps) @1.49g/cm^3.
- Non-hygroscopic.
- Other names include: Cyclotrimethylenetrinitramine (chemical name), Cyclonite (UK), Exogen (France), Hexogen (Russia), Shouyakuand (Japan), T4 (Italy).

Note: Main charge explosives containing a high percentage of RDX include: CH-6, Compositions A, A-2, A-3, A-4, and A-5, Composition B, Compositions C, C-2, C-3 and C-4, Cyclotol, A-IX-I (A-91), A-IX-II, (A-92), DBX, H-6, HBX, MOX, Nitronafita, PBX, PBXN, PBXW (Teflon), PTX, Torpex, to name a few.

HMX: An extremely brisant explosive. It is not used in pure form, but rather mixed with other explosives and desensitizers.

- Color is white.
- VOD, approximately 29,800 fps (9,100 mps) @1.9 gm/cm^3.
- Non-hygroscopic.
- Other names: Cyclotetramethylenetetranitramine (chemical name), Octogen (Germany), Okfol (Russia), Octogere (France) and Octol (U.S.).

Note: Explosives containing a high percentage of HMX include: HTA-3, LX, PBX, and PBXN.

Picric Acid: Used extensively by Japan, Germany, and other countries through WWII. Today, it is used by many countries as the explosive characteristics are very similar to TNT.

- Color is yellow.
- VOD, approximately 23,000 fps (7,000 mps).
- Slightly hygroscopic. Excluding aluminum and tin, it reacts with all metals to form extremely sensitive compounds called picrates.
- Other names include: Trinitrophenol (chemical name), Melinite (French), Lyddite (UK), Granatfullung 88 (Germany), Ercasite (Austria), Pertite, (Italy), Ooshokuyaku or Shimose (Japan), Coronite (Sweden), Picrinite (Spain), and Melinit or M (Russia).

Main Charge and Bursting Charge Explosives: In an explosive train, the main or bursting charge produces the intended results. Characteristics include:

1. Not as sensitive to heat, shock, or friction as primary or secondary explosives. Usually not susceptible to detonation from bullet impact or unconfined burning, and some of these explosives can withstand tremendous impact pressures.
2. Typically comprised of a combination of secondary explosives and other materials designed to produce specific energy output characteristics.
3. Can consist of a single explosive such as cast, flaked, or pressed TNT, but explosive blends are more common.

Examples:

Amatol: A mixture of ammonium nitrate (AN) and TNT ranging from an 80/20 to 40/60 mix. The mixture is reflected in the markings; for example, 80/20 Amatol consists of 80% AN and 20% TNT.

- Color ranges from yellow to brown.
- VOD, approximately 15,000 to 21,000 fps (4,550 to 6,400 mps).
- Very hygroscopic. Reacts with copper, brass, and bronze to form sensitive compounds.
- Other names include: Schneiderite (French), Fullpulver (Germany), Amotolo (Italy), and Shotoyaku (Japan).

Explosive D: An exceptionally insensitive explosive. Used in ordnance designed to withstand tremendous impact before functioning, such as armor and concrete piercing munitions.

- Color ranges from orange to reddish brown.
- VOD, approximately 23,000 fps (7,000 mps).

- Moderately hygroscopic. If moist, reacts with lead, steel, copper, zinc, and bronze to form sensitive compounds.
- Other names include: Ammonium Picrate (chemical name), Pikurinsan Ammonia (Japan), Dunnite (UK), and Pikrinovokislyi Ammonii (Russia).

Composition B: Very common explosive used worldwide, a mixture of RDX and TNT. American mixtures range from a 70/30 to 50/50 ratio. Russian blends are expressed as TG and a number such as TG-40; deciphered T = TNT, G = RDX, and 40 is the percentage of TNT in the mixture. Another identifier used by many countries is simply RDX/TNT or TNT/RDX with the most prominent explosive first.

- Color ranges from tan to brown.
- VOD, approximately 25,000 fps (7,600 mps).
- Non-hydroscopic.
- Other names include: TG-30, TG-40, TG-50 (Russia).

H-6: A mixture of 45% RDX, 30% TNT, 20% AL, and 5% wax. Designed to produce high blast effects.

- Color ranges from gray to silverish.
- VOD, approximately 23,600 fps (7,200 mps).
- Non-hydroscopic. When wet, reacts with all metals except aluminum and stainless steel.
- Other names: None.

Pentolite: Developed during WWII, Pentolite consists of 49% PETN, 49% TNT and 2% wax. In pure form, PETN is as sensitive as primary explosives and thus not often found in ordnance.

- Color ranges from white, to yellow or gray.
- VOD, approximately 24,600 fps (7,500 mps).
- Non-hygroscopic.
- Other names: Pentol (Germany), Pentritol (Italy).

Insensitive Explosives (IE): Some ordnance applications result in deployed munitions experiencing tremendous kinetic energy transfer prior to functioning as designed. As such, there is an ongoing search for insensitive, yet reliable high explosive materials. Further driving this search is the desire for explosive-filled munitions to withstand exposure to shipboard and ammunition storage fires, accidents, and to also deny an enemy the ability of using ordnance in IEDs. See "U.S. IHE Designations" in Appendix D for more details.

An insensitive, high explosive munition may seem like an oxymoron, but with ordnance designs focused on "functioning as designed," the use of an effective IE makes sense, and the safety implications are substantial. Explosive D is an example of an early insensitive explosive. The terms insensitive explosives, or insensitive munitions, are normally associated with plastic bonded explosives (PBX). There are numerous compositions, some of which are used as propellants, with the primary names of PBX-9007, 9010, 9011, 9404, and 9407 to name a few. The U.S. Navy developed plastic bonded explosives, identified with the addition of an "N." These are the PBXN series of main charge explosives.

Research conducted by the U.S. Air Force for the small diameter bomb resulted in the development of the AF-757 explosive. U.S. Army research on artillery projectile fillers developed an insensitive munition explosive (IMX). Additionally, for grenades, mortars and rockets, Picatinny Arsenal Explosive (PAX) was found suitable. Due to the number of different desensitizers and materials used; the colors, VOD, and hygroscopic characteristics of insensitive explosives vary greatly.

Uncharacteristic, But Not Uncommon Main Charges:

During times of war, the logistics required to support the enormous need for raw materials leads to compromise in all areas, including ordnance development.

As an example, in 1897, Frenchman Ernest Street patented a number of mixtures, later referred to as "Street Explosives" (Figure 1.2). As described by Arthur Marshall in *Explosives, Vol. 1* (1917):

> It was discovered by E. A. G. Street, of the firm of Bergen, Corbin et Cie, that the dangerous sensitiveness of chlorate mixtures could be reduced by coating the chlorate with an oily material, such as castor oil thickened by having a nitro-hydro-carbon dissolved in it.

The techniques outlined by Ernest Street appear to be the earliest attempts to reduce the sensitivity of chlorates by coating them with oil, wax, and pitch to name a few.

For over some 1,000 years, countries have searched for explosive compounds that could be used for military applications. The amount of time, effort, and funding applied to this purpose ensures an endless number of potential fillers in an unknown munition. These fillers, if destroyed, may produce a woefully unexpected result. To avoid such outcomes, one must positively identify a munition, and then review the hazardous components prior to determining a means of destruction.

To further clarify this issue, two examples of seldom recognized, but often encountered explosives are provided. Both offer cost-savings, offset by

N° 9970 A.D. 1897

(*Under International Convention.*)

Date claimed for Patent under Sect. 103 of Act, being date of first Foreign Application (in France) 29th Mar., 1897

Date of Application (in United Kingdom), 21st Apr., 1897

Complete Specification Left, 3rd Feb., 1898—*Accepted*, 5th Mar., 1898

PROVISIONAL SPECIFICATION.

Improvements in or relating to Explosives.

I, Ernest Auguste George Street, of 95, Boulevard Beaumarchais, Paris, in the Republic of France, Engineer, do hereby declare the nature of this invention to be as follows:—

The present invention relates to the manufacture of an improved explosive, which is little sensitive to shocks is easily manufactured and resists heat and humidity.

I have found in the course of experiments that nitrated derivatives of organic substances (mono nitrates, binitrates, trinitrates, *etc.*) are soluble in animal and vegetable oils and fats, while they are not at all or very slightly soluble in mineral oil and fats, such as vaseline and paraffine.

These solutions of nitro-compounds in oil crystallize if slowly cooled.

By cooling them rapidly and by stirring a pasty substance on the contrary is obtained, the consistency of which varies according to the proportion of oil and of nitro-compound, and which is perfectly suitable for being mixed with chlorate of potash alone or with hydro-carbonated or carbonated substances such as starch, fecula *etc.*

The mixture of these different substances under the conditions indicated gives a plastic explosive easily moulded, little sensitive to shocks or blows, to humidity and heat, and possessing an explosive power which, according to experiments can be from 6 to 10 times that of black blasting powder.

The nitro-compounds experimented with are of two kinds (1), liquid, as nitrobenzine.

(2) Solid, as nitro-napthaline, binitrobenzine, picric acid.

The proportions of the different bodies may of course vary according to the force resistance to shock *etc.* of the explosive that is to be obtained. By way of example the following formulæ are given.

Figure 1.2 Street explosives. Patent #9970, dated 29 March 1897.

questionable performance. Yet both are still used today by nations, as well as non-state organizations, in their ordnance.

Cheddite: While "Cheddites" are not used in conventional ordnance today, a significant percentage of the munitions manufactured during WWI and throughout the early-1900s were filled with Cheddite. Manufactured by most countries, recipes include, potassium chlorate, sodium chlorate, sodium nitrate, ammonium perchlorate, mononitronaphthalene, nitronaphthalene, dinitrotoluene (DNT), TNT, sawdust, castor oil, and paraffin to name a few. All of these chemicals result in different compositions, with varying sensitivities, speeds, and energy outputs.

Today, Cheddite-class explosives are commonly found in improvised ordnance. An "improvised munition" incorporates the raw materials and

fabrication methods available with conventional ordnance designs and components.

Characteristics include:

- Color ranges from white, yellow, to various shades of gray.
- VOD, approximately 10,000 to 12,000 fps (3,000 to 3,700 mps).
- Hygroscopicity varies with different constituents.
- Other names include: Blastine (UK), Sauranite (France), Alkasit or Parammon (Germany), Victorite or Cannel (Italy), Territ (Sweden), and Almatrit No.19 or Ammonalmatrit No.98 and Kaliialmatrit No.55 (Russia).

DNN: As stated by T.L. Davis, "DNN… begins to show a feeble capacity for explosion," yet it is still used by many countries. For example, France, Russia, and Italy used a mix of 87.5% AN with 12.5% DNN in projectiles during WWI. Common uses today include Chinese made, 82mm and 100mm projectiles filled with DNN. Russia mixes TNT with DNN to make "TD" explosives. Deciphered, TD- and the number such as TD-40 means T = TNT, D = DNN, and 40 is the percentage of TNT in the mixture.

- Color ranges from white to gray.
- VOD, approximately 10,000 to 18,000 fps (3,000 to 5,500 mps).
- Hygroscopic.
- Other names: Dinitronaphthalene.

High Explosives—Configurations and Effects

Military ordnance is capable of producing numerous effects. Only seven specific effects associated with explosive-filled ordnance will be discussed throughout this text. Historically, ordnance has been designed to address a tactical shortfall on the battlefield. Once designed, the effects are manipulated for maximum efficiency. In order to accomplish this, a munition's initial design and configuration must meet the requirements of the weapon system deploying it, as well as the tactical requirements initiating the original design. In practical terms, it is impossible for a single munition to produce all seven effects:

1. **Fragmentation (Frag):** Is characterized by material being projected away from an explosion at high velocities. There are three types of fragmentation:
   a. **Primary frag:** Produced by the warhead, body, or outer case of the munition. Additional enhancements, such as internal

serrations, specially designed fragmentation liners, or external fragmentation sleeves, greatly increase this effect. A careful balance between the chemistry of the explosive filler, and the physical design features including the materials used, shape, case thickness, metal hardness, etcetera, produces the specific fragmentation sizes and velocities needed to meet the required effects on the intended target.

Explosives with a high VOD tend to produce smaller, jagged fragments moving at high velocities. Explosives with a slower VOD usually produce larger, slower moving fragments. The speeds of fragmentation can be calculated using various "Gurney equations."

b. **Secondary fragmentation:** Includes non-explosive munition components such as guidance sections and fins, as well as objects from the target or environment such as glass, metal, rock, and wood splinters.

c. **Shrapnel:** Initially used to identify the 1790s design by British artillery officer Henry Shrapnel. The name carried over to the elongated projectiles used in the mid-1800s with similar internal designs. Examples of common shrapnel projectiles include:

   i. A projectile filled with shrapnel and pitch, with a Powder-Train-Time-Fuze (PTTF) and burster lead running from the fuze, through the center of the munition to a bursting charge (Figures 13.4 and 13.5). Shrapnel usually consisted of .69 caliber musket bullets, but during times of logistical shortfalls, nuts, bolts, metal slag, rocks, and other materials have been utilized. Functioning over the heads of troops, fragments from the shell and its shrapnel payload were propelled in all directions.

   ii. An elongated projectile with the forward 80% filled with shrapnel, and a PTTF connected to the explosive charge in the base by a hollow flash-tube (Figure 1.3). Shrapnel usually consisted of .69 caliber lead or iron balls.

   Upon functioning in the air above troops, the fuze and shrapnel were propelled in a forward direction as seen in Figure 1.3, while the body of the munition remains intact. The resulting effect is much like a flying shotgun cartridge functioning close to the target, dispersing its contents in a specific direction.

2. **Blast:** A complex interaction of many variables, but primarily involves the shock-front traveling outward from the point of detonation. The shock-front pushes the surrounding environment outward and is followed by blast pressure or overpressure.

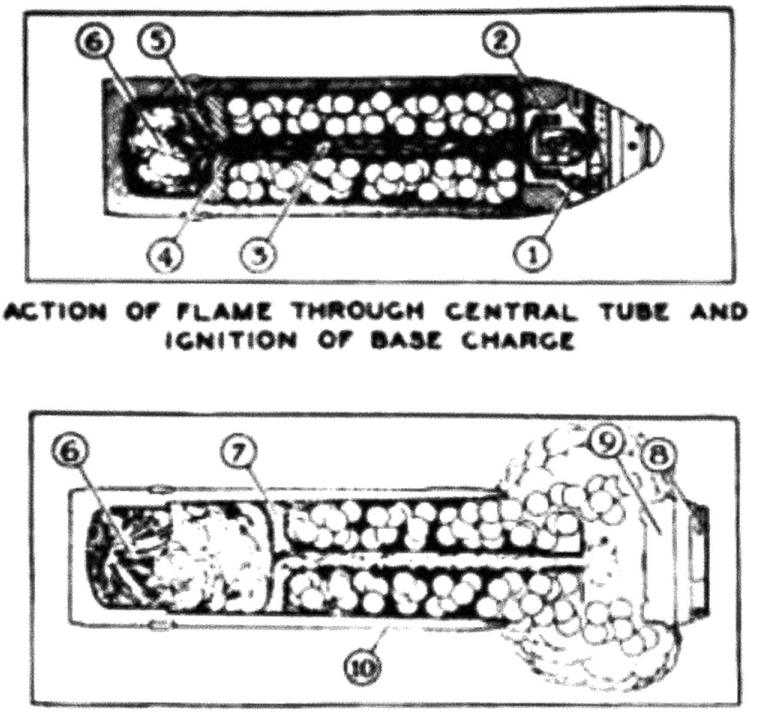

Figure 1.3 Top illustration: Upon functioning, the fuze (1 and 2) send a flame down the spit-back tube running to the base (3), some designs incorporated a guncotton charge as a booster (4) at the diaphragm (5) to initiate the black powder base-charge (6). Bottom illustration: The exploding black powder forced the diaphragm (7) forward causing the fuze and fuze adapter (8 and 9) to separate, while the projectile body (10) remained intact. (From U.S. Military TM.)

The effects of blast in open air, enclosed spaces, underground, and underwater are very different. For example, when the shock-front impacts a surface, it reflects causing a Mach Stem, which is the result of the converging overpressures where the shock-front meets reflected shock-fronts (Figure 1.4). The Mach Stem effect almost doubles pressures a short distance off reflecting surfaces. As this is a consistent effect, there are ordnance items specifically designed to maximize these extreme overpressures for specific applications.

3. **Incendiary:** Unlike the dramatic fuel-enriched fireballs common in movies, the incendiary effect of a high-explosive detonation is a "quick flash" that can be missed in the blink of an eye. In military ordnance this effect is often enhanced with red or white phosphorus and metals such as zirconium, aluminum, and magnesium. The Pyrotechnics, Incendiaries, Pyrophorics, and Smoke Producing Compounds section of this chapter contains information on these materials.

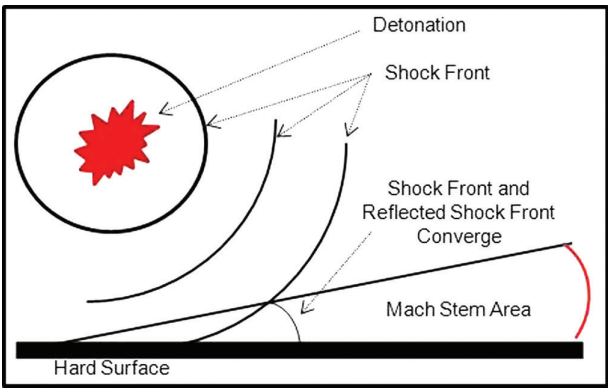

Figure 1.4 Illustration of Mach Stem region. (Author's graphic.)

4. **The Munroe Effect—Shaped Charge or Hollow Charge:** There are few absolutes associated with explosives. However, one constant is how energy can be directed by shape and enhanced by configuration.

   Labeled as directional loading or the flat-surface concept, explosive force will always load and be consistently focused in the direction of a flat surface. When two flat surfaces are aligned in a converged linear shape, or a continuously converging conical cone-shape, the energy from these offset flat surfaces converge, resulting in a tremendous amount of energy being focused on a very small area, which creates a plasma jet, or "rod," capable of penetrating armor with small amounts of explosive. After jet formation, the remnants of the cone material will form into a slug. Upon either penetrating or missing the target, the slug can travel for many kilometers (Figures 1.5 and 1.6).

   Charles Munroe, a scientist at the U.S. Naval Academy, is credited with discovering this repeatable effect in 1888. Though others claim to have discovered the shaped-charge first, it is commonly known as the Munroe effect.

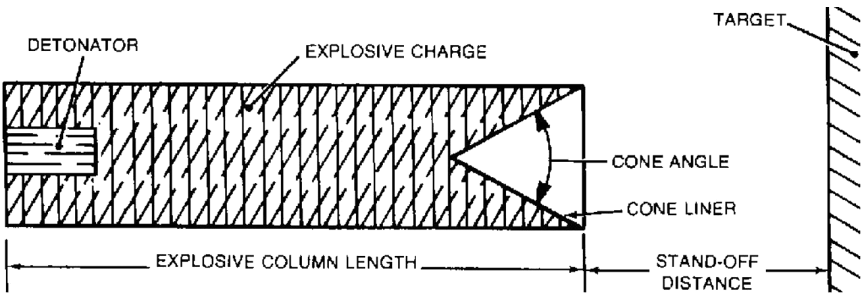

Figure 1.5 Shaped Charge configuration. (From U.S. Military TM.)

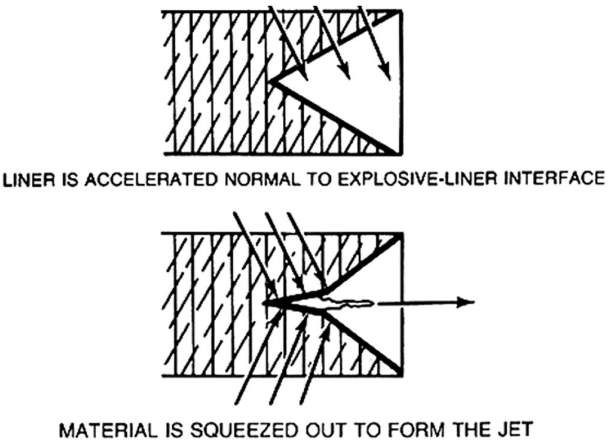

Figure 1.6 Shaped Charge Jet formation. (From U.S. Military TM.)

Capable of penetrating armor, this configuration was quickly applied to ordnance designs. Shaped-charges are used extensively in military ordnance. So much so, that any warhead or munition containing one is "grouped" as a High-Explosive Anti-Tank (HEAT) munition. A properly constructed conical shaped-charge can penetrate armor over six times thicker than the charge diameter.

For a shaped charge to produce its intended effect, four factors must be present at the moment of initiation.

i. **Explosives:** Brisant explosives are required to generate the greatest results.
ii. **Point of Initiation:** Conical shaped-charges must be initiated at their base on the center axis over the cone. If the charge is initiated from any other point, the jet will not be as effective or will fail to form at all (Figure 1.5).
iii. **Standoff Distance:** Upon initiation, a shaped charge must be a specific distance from the target to allow the jet to form for optimal performance. If it is too close or too far from the target, penetration will be degraded (Figure 1.5).
iv. **Cone Specifications:** Orientation, liner, and angle.
    a. **Orientation:** The open end of the cone must be oriented directly toward the intended target.
    b. **Liner:** The cone liner must be a pliable material at high temperatures. While copper is a common liner material, glass and other materials are also effective. However, the centrifugal force exerted to spin-stabilize a projectile, also has a negative effect on jet formation. As a result, fin and fin-spin stabilized munitions contain a smooth liner, while spin

stabilized munitions utilize a fluted liner to counteract the spin and ensure proper jet formation and maximum effect. An example of a fluted cone is provided in Figure 3.8 in Chapter 3.

c. **Angle:** An important geometrical consideration is the angle of the cone apex. Since different angles produce different effects, target specific configuration are required. For example, shallow angled cones provide less penetration over larger surface areas given that they move more slowly and pull more material from the liner. The trade-off for these conditions is the production of a large entry hole.

   Steeper angled cones move faster, focus on a smaller surface area, use less material from the liner, but produce much deeper penetration. As a rule-of-thumb, a 42° angle is considered optimum for providing a balanced speed-to-liner-mass ratio effective against most target materials (Figures 1.5 and 1.6).

5. **The Miznay-Schardin Effect—Explosively Formed Projectile (EFP):** The fundamental directional loading, flat-surface concept also applies to EFPs, but in a slightly different way. The effects produced when explosive focus is applied to a slightly concaved surface, initiated on the center axis of the base over the concaved plate are extreme (Figure 1.7). The resulting EFP combines extremely high velocity with the mass of a heavy copper liner capable of penetrating armor and other hardened targets.

   As with shaped-charges, the effects of an EFP are greatly enhanced when brisant explosives are used. After penetrating or missing a target an EFP can travel for many kilometers.

   Other than landmines, EFPs have limited use in military ordnance. The extended standoff requirements for an EFP to function correctly, ultimately limit delivery options.

6. **Craters and Camouflets:** When an explosion takes place on the surface, a shallow open crater is formed. A subsurface explosion capable of breaching the surface will form a "true crater." An understrength

Figure 1.7 Explosively Formed Projectile (EFP). (From U.S. Military TM.)

subsurface explosion will result in a void or "camouflet" under the surface that is difficult to detect. Munitions designed to produce a camouflet are target specific and complex, resulting in additional hazards when they fail to function.

7. **Spalling:** When armor is impacted by a fast moving, dense object, or when an explosive is placed in contact with armor and initiated, the metal is impacted, compressed, and pushed away from the point of impact or detonation, causing an intense shock wave to move through the armor. If strong enough, when the shock wave abruptly stops on the opposite side, interior metal flakes off and continues traveling away from the energy source. These metal fragments or flakes are called "spall."

Introduction to Low Explosives and Propellants

Low Explosives (LE): Are characterized by a chemical composition capable of exploding, but unable to support the self-sustaining shockwave required to be a high explosive. When unconfined, low explosives may burn, deflagrate, or explode; but are more likely to explode when confined. LE are utilized extensively in ordnance to fire projectiles, launch rockets, missiles, torpedoes, as well as other applications. Unless otherwise stated, "LE" will be associated with propellants throughout this text.

Black Powder: The history of black powder is the history of military conquest. The original date of discovery is unknown and may have been a tightly held military secret for decades before first being mentioned in Chinese literature in 1004. By 1067, the Chinese government had placed key ingredients under military control, banned export sales, and made the recipe a state secret.

Still used today, black powder is the longest continuously used military explosive. A conventional black powder mixture is 75% potassium nitrate, 15% charcoal, and 10% sulfur, or a sodium nitrate, coal, and sulfur mixture in slightly different proportions. The "form" or shape of black powder can range from a fine powder to grains over half an inch in diameter. The burn-rate of black powder is subject to many variables, but can exceed 1,200 fps (365 mps). Today, the exact mixture used by the Chinese over 1,000 years ago is not known.

Until the early 1900s, black powder was used for almost all explosive main charges, fuzing systems, bursting charges, propellants to fire projectiles, as well as rockets. Today, black powder is used in pyrotechnic delay fuzes, self-destruct delay elements, expelling charges, bursting charges, and other ordnance components.

Though very hygroscopic, black powder is extremely sensitive to sparks and static electricity. When stored in a sealed container, black powder will remain stable for extremely long periods of time. For example, there have

been numerous instances of people killed or horribly injured while attempting to inert Civil War ordnance from the 1860s. In most cases, these people were killed while working on projectiles recovered from battlefields.

Propellants: React to the same types of stimuli as high explosives. Many propellants contain high explosives with stabilizers and other materials to produce specific burn rates and required thrust. As such, there are many chemical compounds used to propel munitions, dispense ordnance payloads, or move internal components.

Propellants may be composed in either solid or liquid form. Solid propellants are used to fire or propel projectiles. Liquid propellants are more commonly used in large rocket motors and underwater ordnance.

Many performance characteristics of a propellant are determined by the burn rate, which is the rate at which gases are generated by a burning propellant. It is the propellant equivalent of the VOD used to characterize HE material. The performance characteristics, specific formulations, and configuration of a propellant are then used to complete the design factors that maximize munition efficiency.

A few definitions relevant to propellants are provided below. Additional definitions and abbreviations are available in Appendices B, C, D, E, and the Bibliography.

Class: The chemical composition of a propellant.

Form: The shape of a propellant (Figure 1.8).

Burn Rate: The speed at which the reaction zone progresses through or consumes a propellant.

Force Constant (f_v) of a Propellant: Is a means of expressing the quantity of gas produced when propellant burns. Also known as propellant force or propellant impetus.

Burn Types: Various forms are used to control how propellants burn. While burning, the surface area can increase, decrease, or remain constant.

1. Degressive Burn: A form with decreasing surface area, and thus decreasing force as it burns.
2. Neutral Burn: A form maintaining a constant surface area, and thus consistent force as it burns.
3. Progressive Burn: A form with increasing surface area, and thus increasing force as it burns.

Most explosives used by the military decompose slowly, even under extreme conditions. However, propellants containing nitrocellulose and other unstable materials tend to decompose quickly. Damaged and deteriorated propellants are capable of inadvertent initiation and other malfunctions. If dropped, solid propellants are prone to cracking; whereas liquid propellants are prone

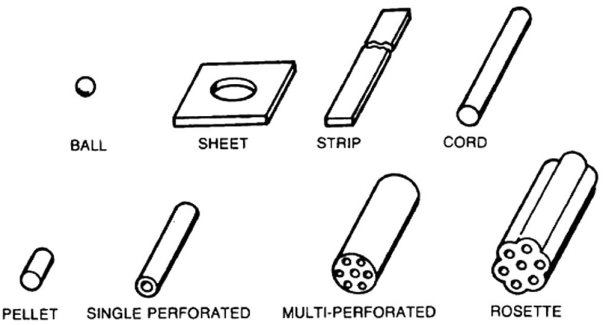

Figure 1.8 Examples of propellant forms. (From U.S. Military TM.)

to leakage, and most have an associated "chemical" safety precaution due to toxicity. Details on the chemical safety precaution are provided in Chapter 2.

Low Explosives and Propellants—Groups

In order for a propellant to function as designed, components are aligned from the most to least sensitive. In a low-explosive train, this is the means by which a flame is amplified to ignite larger quantities of propellant. Components of a propellant firing training include (Figure 1.9):

a. **Primer or Squib:** The smallest, most sensitive component in the train. Non-electric primers function upon impact, while electric primers or squibs are initiated by electric current. When a primer or squib functions, a small flame is produced and passed on to the igniter.
b. **Igniter:** Amplifies the flame from the primer or squib to ignite the main propellant charge.
c. **Propellant:** Receives the flame from the igniter or squib and functions as designed.

Low Explosives and Propellants—Effects and Configurations

Due to the complex chemistry and classified nature of many liquid and some solid propellants, detailed constituent lists are seldom available. Additionally, some of the materials found may require explanation. For example, many countries add lead configured into what appears to be a piece of 10-gauge wire rolled into a loose ball about ½" (12.7mm) diameter on the end of a short length of wire. The purpose of adding lead is to reduce muzzle flash, while also providing lubrication to reduce wear on the barrel. The addition of lead,

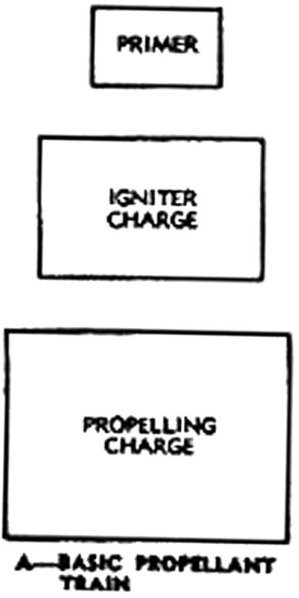

Figure 1.9 Basic propellant firing train. (From U.S. Military TM.)

which is aerosolized when the propellent explodes, also adds a heavy metal inhalation hazard to the smoke produced when the gun is fired.

Four propellant classes are discussed in this text: single base, double base, triple base, and composites:

Single-Base Powder (SBP): Composed of nitrocellulose; which is a high explosive with a VOD of 24,000 fps. SBP is very sensitive to heat, shock, and friction. The addition of other compounds reduces sensitivity; however, the nitrocellulose content in most SBPs is greater than 85%.

- Applications: Small-diameter SBPs are used in small arms ammunition and small rocket motors. Larger "web-shaped" SBPs are used in artillery propellants.
- SBP is hygroscopic over time.

Double-Base Powder (DBP): Composed of nitrocellulose and nitroglycerin. While this mixture increases the energy potential and burning temperature, the increased temperatures will rapidly deteriorate barrels.

- Applications: DBP is primarily used in small arms ammunition, smooth-bore and one-shot "throw-away" weapons, and some rocket motors.
- DBP is hygroscopic over time.

Triple-Base Powder (TBP): Composed of nitrocellulose, nitroglycerin, and nitroguanidine. Approximately 50% of the mixture is nitroguanidine, which increases the energy potential. Nitroguanidine burns much cooler than nitroglycerin without sacrificing energy output.
- Applications: TBP is primarily used for large-caliber artillery.
- TBP is hygroscopic over time.

Composite: There are many different formulations qualifying as a composite propellant. Most are composed of a fuel such as aluminum, binders such as synthetic polymers that can also contribute as a fuel, and oxidizers such as ammonium or potassium perchlorate.
- Applications: Composite propellants are used in rocket, missile, and booster motors; as well as base-bleed extended range projectiles (see "Fumer" Appendix C).
- Hygroscopicity rates vary.

Forms of Propellants

Forms are used to manipulate the energy output of a propellant to ensure it meets the performance requirements of the munition. The definitions below correspond with forms in Figure 1.8.

Cord: Produces rapidly increasing pressure that quickly peaks, then gradually tapers off as the surface area of burning propellant decreases. Classified as a degressive form, cord is common in small arms, small rocket motors, and small-caliber artillery.

Single-Perforation: Provides a constant surface area while being consumed. As the outer surface area decreases, the inner surface area increases, allowing pressure production to remain constant. Classified as a neutral form, single-perforation is used in rifle ammunition and larger rocket motors.

Multiple-Perforation and Rosette: Increases the overall surface area as the propellant burns. Resulting in initially low pressures that gradually increase as the propellant is consumed. Classified as a progressive form, multi-perforation is used in large-caliber artillery or where extremely high velocities are required.

Pyrotechnics, Incendiaries, Pyrophorics, and Smoke Producing Compounds

Materials capable of burning are used extensively in ordnance to illuminate the night, function fuzing, produce colored smoke, or to enhance explosive effects.

Pyrotechnic Compounds

Are used extensively and the luminous intensity is measured in candlepower. Commonly recognized examples are projectile tracer elements and signal flares. For flare compositions, fuels, oxidizers, binding agents, retardants, waterproofing materials, and intensifiers are used. All of these materials are manipulated to control burn times, colors, and the intensity of the light and smoke produced.

One of the older, yet lesser known pyrotechnic compounds used in ordnance is photoflash powder. When ignited, this mixture of oxidizers and metallic fuels technically burns, but produces sounds similar to an explosion with a significant blinding-white flash. For example, the U.S. made a 500lb photoflash bomb capable of producing 4.1 billion candlepower. Details on the fire safety precaution associated with these compounds are provided in Chapter 2.

Incendiary Materials

Are typically used to mark or destroy targets with intense heat and fire. Early in military history, burning an enemy in battle was a common tactic utilizing oil, pitch, sulfur, and other volatile materials. By 672AD, a recipe was obtained by the defenders of Constantinople known as "Greek fire." Offering a technical and tactical advantage, Greek fire was used to successfully defend Constantinople for almost 800 years. As with black powder, the exact mixture of the original Greek fire is unknown as death was the punishment for sharing the secret mix.

Today, napalm and white phosphorus are examples of Greek-fire-like, liquid incendiary materials. There are different napalm mixtures, with most containing a hydrocarbon fuel mixed with thickeners, or a mixture of magnesium powder, gasoline, and polyisobutadiene; all of which need to be ignited while or after being deployed.

One of the most common incendiary materials used in ordnance is white phosphorus (WP), which immediately ignites upon contact with oxygen. WP munitions are defined as "bursting smoke" versus incendiary ordnance due to the intended tactical use. The smoke produced by WP is bright white and filled with particulates. The smoke can be easily spotted in almost any environment, and the high particulate count effectively blocks laser designators used to guide ordnance.

In addition to napalm, WP and other similar compounds, solid materials may also be utilized for incendiary effects. Providing "anti-materiel" effects when burning metal is projected from a detonation; pellets, chunks or liners of zirconium, magnesium and other metals are used to enhance the effects of a munition.

Details on the chemical and fire safety precautions are provided in Chapter 2.

Pyrophoric Materials

Thermobaric and incendiary munitions offer examples of pyrophoric materials used in ordnance. An example of a multi-use liquid is TriEthylAluminum (TEA), which is hypergolic upon contact with air or water; however, the energetic diversity of TEA allows it to be used as a thermobaric-explosive warhead with incendiary effects, as well as fuel in large rocket motors.

Other Smoke Producing Compounds

Many pyrotechnic, incendiary, and pyrophoric materials produce smoke. The compounds covered in this section are specifically used for their smoke producing qualities. However, from a safety perspective, all smokes are not alike.

Colored Smoke: Compounds used in ordnance to produce colored smoke for signaling and screening. Classified as "burning smoke," these munitions pose a fire hazard as they burn to produce smoke. Unlike bursting smokes, the reacting materials remain within the munition as smoke and a small amount of flame emits through vent holes in the munition's body. Sublimed organic dyes and inorganic salts are used to produce various smoke colors. The most common colors used are red, green, violet, and yellow.

White Smoke: There are a few compounds used to produce white smoke, all of which are significantly different from colored smokes. Three examples of materials used to produce white smoke are provided below. All three require adherence to the "Chemical" safety precaution, provided in Chapter 2:

1. Hexachloroethane, Aluminum, and Zinc Oxide "HC:" A solid composition that burns to produce a grayish-white smoke. The reaction forms zinc chloride and hydrochloric acid. Commonly deployed in similar configurations as colored smokes, HC smoke is toxic in field concentrations requiring adherence to the chemical safety precaution.
2. Titanium Tetrachloride "FM:" A liquid, mechanically or explosively dispersed to produce dense white smoke. The reaction forms hydrochloric acid. Commonly deployed as a spotting charge, FM smoke is toxic in field concentrations requiring adherence to the chemical safety precaution.

3. Chlorosulphonic Acid "FS:" A liquid, mechanically or explosively dispersed, to produce dense white smoke. The reaction forms hydrochloric and sulfuric acids. Commonly deployed as a spotting charge, FS smoke is toxic in field concentrations requiring adherence to the chemical safety precaution.

Closing

The list of explosives, pyrotechnics, pyrophorics, and other reactive materials and compounds used in ordnance is extensive. However, a comprehensive understanding of these materials and how they interact and work is required to appreciate the threats they pose, and to understand how to apply the safety precautions covered in Chapter 2. Additionally, this understanding will greatly increase the level of safety required when working with military ordnance.

The Fundamentals of a Practical Process

2

Scientific method refers to the body of techniques for investigating phenomena, acquiring new knowledge, or correcting and integrating previous knowledge. It is based on gathering observable, empirical and measurable evidence subject to specific principles of reasoning.

Sir Isaac Newton, 1687

Introduction

The application of the scientific method in the form of a practical deductive process is required to interrogate, assess, and correctly identify unknown ordnance. The processes outlined in this chapter are the core methodology used by the military Explosive Ordnance Disposal (EOD) field, which also harmonize well with those applied by battlefield archaeologists.

An archaeological approach to the recovery of an artifact is a scientifically systematic process that starts with an open mind, followed by the development of working hypotheses based on what can be observed and all available information. Subsequent to these principles are methodical excavation, careful examination, and research of appropriate literature. Throughout these processes, deductions based on the facts and experience of the examiner result in constantly evolving, multiple working hypotheses. Consistent execution of this methodology will eliminate as many possible hypotheses as feasible, allowing more specific hypotheses to develop for further examination and research. Ultimately, the application of this process will result in accurate identification, a safer work environment, professional credibility, additional technical information on the item, and a more complete understanding of the past as well as the present.

For centuries, nations have employed the brightest chemists, physicists, tacticians, and engineers to gain and maintain technical and tactical advantages. Historically, advantage equaled survival, and the result was a vast number of ordnance designs, many of which were never properly documented, making positive identification of unknown ordnance extremely important but also challenging.

Throughout this text, practices that allow safe inspection of unknown ordnance to continue are explained. The dangerous features of these munitions

are presented to preclude minimization of what may constitute substantial threats. The process begins with the assumption that an unknown munition contains all possible threats, and constantly evolves until the Seven-Step process is completed (Figure 2.1). The evidence used to make many of these decisions is imprecise, variations in manufacturing techniques and materials used to construct ordnance further ensure nothing is absolute. The result is lexicon laced with terms such as "usually," "consistent with," "more often than not," "a rule of thumb," followed immediately by "an exception to the rule," and oftentimes "an exception to a specific exception."

The single constant is that ordnance, once out of military control, may be armed, damaged, deteriorated, modified, and contain additional hard-to-recognize hazards. To address these variables, the Seven-Step process focuses on construction features that help determine the Category, Group, and Type to which a munition belongs.

Category, Group, Type, and Size Definitions

Over the last 1,000 years, millions of different ordnance designs, types, and models have been created. Many were manufactured by nations that do not exist today. Thus, a classification system, based on how ordnance is designed for deployment and purpose is used to organize this information. The system

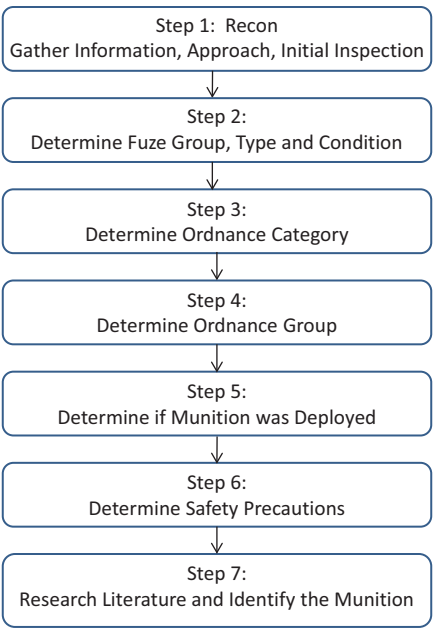

Figure 2.1 The Seven-Step process. (Author's graphic.)

is broken down into categories, groups, and types to provide a basic classification structure. In addition to the research-related benefits, this system is also directly linked to field processing and safety. For example, many safety precautions are associated with specific designs, and documentation for many specific munitions does not exist. By accurately categorizing and grouping an unknown munition, unrelated precautions are dropped, leaving only those associated with that specific design. In these situations, while a munition may not be positively identified, its associated threats can be established and considered before further actions are taken.

The overall design, materials, and methods of construction used for all ordnance is limited by the rules of physics, chemistry, and engineering, as well as the manufacturing capabilities of the country, or person making the munition. The results are unique characteristics that can be used to classify the category or group to which a munition belongs. Using this classification system as a guide, subsequent chapters will cover the shapes, designs, construction features, materials, and associated safety precautions. All of this evaluation process begins with a few important definitions:

Perspective: When interrogating unknown ordnance, regardless of location, a munition is always assessed from a down-range perspective. Whether a munition is on a shelf, set in the trunk of a car, or inside a foot locker, a munition is always assessed as if it was correctly deployed and currently resting on a battlefield. When universally applied, communications, research, and accurate identification are enhanced and align with military classification systems.

Category: Defines the means of deployment or intended application of a munition. It is the fundamental class a munition falls under. If deployed, "Category" answers the question "how did it get here?"

Group: Defines the effect the munition is designed to produce upon functioning. If deployed, "Group" answers the question "what was it supposed to do when it got here?"

Type: Primarily limited to fuzes, launch platforms for rockets and missiles, and a small number of other munitions; type cannot be applied universally. When a "Type" can be determined, the additional specificity makes identification much easier.

Color Codes and Marking Schemes

Ordnance is painted or anodized to prevent corrosion and offer a means of identification. Colors and marking schemes can include single colors or complex combinations of background and foreground colors, numbers, letters, words, bands, disks, squares, and other symbols or color patterns to identify the "Group" to which a munition belongs.

That said, ordnance can be repainted, color schemes can be distorted or completely removed by impact with a target or exposure to the elements. Additionally, most countries apply slightly or completely different color code schemes. For example, the United States currently applies its third generation of color schemes developed over the last 100 years. The current marking scheme for projectiles manufactured in the U.S. are displayed in Figure 2.2, but there are many exceptions. The Russian projectile marking scheme is displayed in Figure 2.3. Additional information on U.S. and Russian markings are available in Appendices D and E.

It is important to note that the color codes and markings being discussed do not apply to small arms, blanks, cartridge cases, fuzes, demolition charges, and many pyrotechnic devices.

Stamped Markings

In addition to paint, many ordnance items have important information stamped into the metal as a dependable means of identification. Used by most countries, these markings may include the munitions nomenclature, model number, serial number, and other referenceable information. Stamped markings are difficult to deface, more apt to survive impact and exposure to the elements (Figure 2.4). Base stamped markings are common on Russian projectiles, but the U.S. and many NATO countries limit this practice to Naval projectiles.

In contrast, submunitions, small landmines, and many external and internal components of larger ordnance items may not have stamped, stenciled, or painted markings of any kind. It is also important to note that once outside military control, ordnance stamped INERT or EMPTY, may have been refilled with energetic materials.

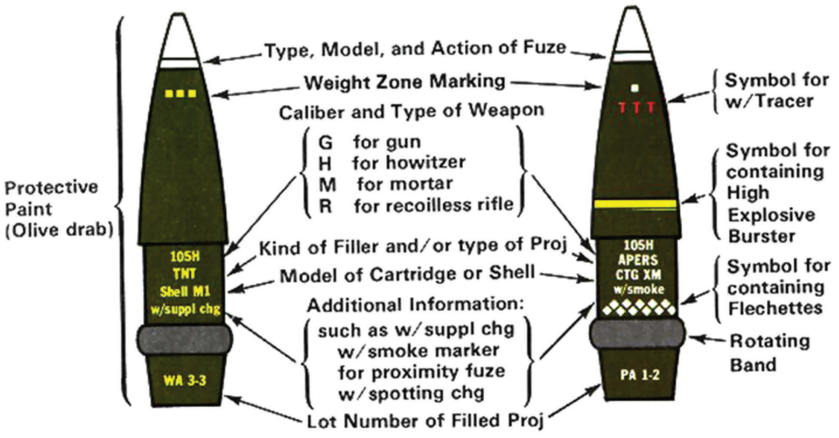

Figure 2.2 U.S. Projectile marking scheme. (From U.S. Military TM.)

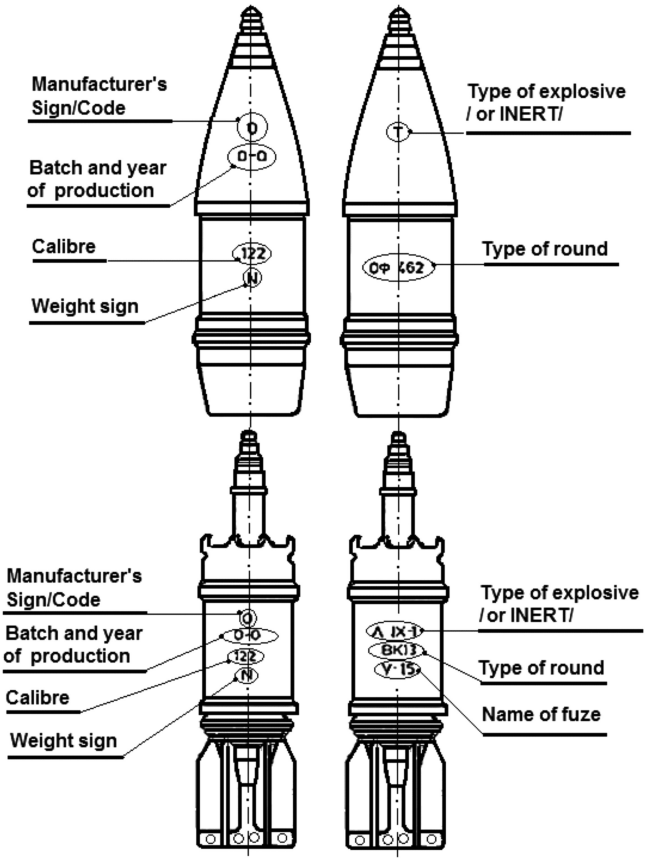

Figure 2.3 Russian projectile marking scheme. (From Former Warsaw Pact, Ammunition Handbook.)

Figure 2.4 Stamped markings on Japanese fuze. (Author's photograph.)

Seven-Step Practical Process

For practical application, seven steps are used to define each aspect of the ordnance identification and evaluation process. When properly applied, this process greatly increases the probability of an accurate identification. Which starts with the realization that ordnance is inherently dangerous. As such, approach constitutes a decision point. For safety, the overall mindset is that the unknown munition may contain the most hazardous features possible and is in a hazardous condition.

Although situations vary and the sequence of the seven-steps may change (Figure 2.1), the systematic application of all seven steps is required to successfully identify and determine the safety requirements associated with a munition. Steps 1 and 7 are the only two remaining constants as every identification starts with an initial inspection and ends with an identification or determination of "unknown." From the moment step 1 begins, steps 2, 3, 4, 5, and 6 are simultaneously addressed and answered as soon as possible.

Depending on the munition and environment, some characteristics may be more easily recognized, allowing some steps to be answered quickly. Those steps remaining unanswered warrant additional consideration during step 7.

Step 1: Approach and Initial Inspection:

Figure 2.5 shows a basic Recon-Kit. The flexible measuring tapes are for round or awkwardly shaped items. The 550 cord is handy for long or large diameter items. In addition to the tools photographed, consider adding small binoculars, a small mirror, a pen, paper, and a compact digital camera. If a portable x-ray is available, it is a valuable tool for inspecting internal components.

Start by attempting to identify the munition from a safe distance with binoculars. If this is not possible and a closer look is required, attempt to determine the front and rear of the munition. Then approach at a 45° angle from the rear, avoiding venturis and fuze sensing elements. Damaged or armed-active sensing elements may "see" or sense movement, consider it a valid target, and function as designed.

Approach the unknown item until it is in view, stop, and begin to address steps 2 through 5, while adhering to the relevant safety precautions outlined in step 6. Until a munition has been conclusively identified and deemed safe to move, do not manually move or touch it. Under no circumstances are plungers depressed, vanes rotated, pins removed or replaced, levers or any other external features moved, as these actions may arm or function a munition.

Safety Concern: Many tools used to assemble ordnance are not commonly available. If a wrench and other inappropriate tool-marks are noted during inspection, STOP! Military ordnance, especially practice hand

Figure 2.5 Basic Recon-Kit. Includes inner and outer calipers, magnifying or fingerprint inspection glass, small light, compass, flexible and rigid measuring scales in metric and standard for documentation and photography. (Author's photograph.)

grenade bodies, are often illegally reconfigured and filled with energetic materials. With no legitimate reason for the presence of these unusual toolmarks, or means of immediately determining what was modified, it must be assumed the munition will not function as designed. If evidence of modification exists, the munition in question is classified as an Improvised Explosive Device (IED).

Begin the inspection at one end of the munition and work to the other end, taking note of all identifying construction features. Make a rough sketch of the area, photograph the item, and document measurements and identifiable features. The single "absolute" associated with ordnance is that everything on a munition serves a purpose and also provides insight into its identity.

At a minimum, ensure the width and length of the fuze, individual sections, and the overall munition are documented. Then document other identifying features including fins, rotating bands, venturis, leaking material, color codes, stamped markings, distinct construction features, damage, signs of tampering or modification. If severely damaged, take the best

measurements possible and document the damage, especially where components might be missing or crushed from high-speed impact.

Upon completing an inspection, exit the area via the route taken on approach and return to the safe area.

Step 2: Determine Fuze Group, Type, and Condition (Logic Tree 3, Appendix A):

The fuze constitutes the brains of a munition, and there may be two or more fuzes present. If maximum consideration is given to ensuring the fuze does not function, the threat of the munition causing harm is greatly reduced. A clearly visible, undamaged fuze is easy to identify. If the fuze is internal or severely damaged and cannot be seen, its "type" may still be determined due to the category and group to which the munition belongs (steps 3 and 4). If the munition has been deployed, the fuze is considered armed (step 5). If a fuze is damaged, or components such as pins or clips have been removed, the fuze is considered armed. If the munition shows signs of alteration or modification, consider the munition armed as the internal configuration is now unknown and may include an alternate fuzing system.

Measurements of the fuze are taken separately from the munition.

Step 3: Determine Ordnance Category (Logic Trees 1 and 2, Appendix A):

Ordnance is deployed by being thrown, dropped, fired, launched, or placed. In many cases, category can be determined by the presence or absence of specific external features.

Step 4: Determine Ordnance Group (Logic Tree 2, Appendix A):

Group further defines a munition's designed effect. In many cases, group can be determined by the presence or absence of specific external features.

Step 5: Determine if Munition was Deployed:

If an ordnance item has been deployed and failed to function, it is classified as unexploded ordnance (UXO). Terms such as "dud fired" or "dud" are also commonly used. A munition that was deployed and failed to function is in the most dangerous condition.

Step 6: Determine Safety Precautions that Apply:

Every munition has a purpose; if that purpose can be ascertained, then most, or all of the associated hazards can also be identified.

There are 16 fundamental safety precautions associated with military ordnance and additional safety precautions related to specialized munitions not included in this text. These precautions are designed to clearly and concisely state what actions are to be taken, or explicitly avoided. Every precaution resulted from lessons learned after an accident, mishap, or catastrophe.

When an unknown piece of ordnance is encountered, all 16 safety precautions are initially adhered to. Throughout the inspection process, safety precautions associated with categories and groups that can be ruled out are dropped. The remaining safeties are adhered to until the incident is resolved.

The safety precautions are not provided in a specific order. Consider rearranging them to make a word or phrase to assist in easy memorization. They are high explosive, fragmentation, electromagnetic radiation, static, movement, jet, ejection, chemical, fire, white phosphorus, cocked-striker, wait-time, variable time/proximity, piezoelectric, booby-trap, and influence.

1. High Explosive (HE):
   a. Hazard: Explosive blast and overpressure.
   b. Actions:
      i. Do not expose to heat, shock, or friction.
      ii. Establish a 360° by 300-meter exclusion area around the munition.
      iii. People within the exclusion area need adequate frontal protection.
      iv. When the actual threat is realized, increase the exclusion area if necessary.
2. Fragmentation (Frag):
   a. Hazard: Primary and secondary fragmentation.
   b. Actions:
      i. Establish a 360° by 300-meter exclusion area around the munition.
      ii. People within the exclusion area need adequate frontal and overhead protection.
      iii. When the actual threat is realized, increase the exclusion area if necessary.
3. Electromagnetic Radiation (EMR):
   a. Hazard: Unintentional initiation. EMR is electrical energy produced by radios, radars, cell-phones, and other electronic devices. EMR can initiate fuzing and other electronic components, especially if the munition is damaged.
   b. Actions: Do not use radio, cell-phone, or other electronic devices near an unknown ordnance item.
4. Static:
   a. Hazard: Unintentional initiation. Static can initiate fuzing and other electronic components, especially if the munition is damaged.
   b. Actions:
      i. Do not wear wool or nylon clothing when working with ordnance.
      ii. Discharge static by placing the back of the hand on dirt or grasp a grounded item.

5. Movement:
   a. Hazard: Unintentional initiation. Many fuzes, contain free-floating impact or inertia weights, cocked-strikers and other hazards that are extremely sensitive to movement.
   b. Actions: Do not move. Positive identification and condition determination must be made prior to considering if a munition can be moved.
6. Jet:
   a. Hazard: A shaped charge jet penetrates armor for short distances, but the remaining material from the cone is deformed into a teardrop shaped "slug" capable of traveling for miles past the target. An EFP also forms a slug that constitutes a similar enough hazard that both are covered under "jet."
   b. Actions:
      i. Approach at a 45° angle from the rear.
      ii. Do not orientate a munition toward populated areas.
      iii. Due to the frequent use of piezoelectric (PE) fuzing in these munitions, also adhere to PE, EMR, and Static safeties until a PE fuze is ruled out.
7. Ejection:
   a. Hazards:
      i. Components forcibly ejected during deployment, such as explosively ejected submunitions, pyrotechnic candles, fin assemblies, and fuzing probes.
      ii. For ordnance with motors, ejection applies to the areas in front of and behind the munition, as well as in front of venturis that may be on the base or side.
   b. Actions:
      i. Approach at a 45° angle from the rear.
      ii. Work outside areas where fins, probes, payloads, and other hazards would deploy.
      iii. Do not move in front of or behind a munition containing a motor.
      iv. People in potential back-blast or flight path zones should move to a safe area.
8. Chemical:
   a. Hazard: Contact contamination or inhalation of chemical weapons, riot control agents, smoke from burning pyrotechnics, heavy metals used in guidance systems, toxic propellants, some screening smoke mixtures, and explosive main charges, such as the chemicals used in fuel air explosive (FAE) munitions.

   b. Actions:
      i. Establish a 360° by 450-meter exclusion area around the munition and a 2,000-meter downwind hazard area.
      ii. Wear appropriate personal protective equipment (PPE).
9. Fire:
   a. Hazard: Intense fire. Applies to munitions containing pyrophoric, pyrotechnic, and incendiary components or payloads.

      Additionally, do not spray or dump water on burning flare compositions, incendiary compounds, and pyrophoric materials as the "thermal shock" can produce a significant mechanical explosion.
   b. Actions: If a munition is burning,
      i. Do not inhale the smoke and move away in an upwind direction.
      ii. Establish an exclusion area in accordance with the "Chemical" safety precaution.
      iii. Never approach a burning or smoking munition.
      iv. Expect a higher-order detonation.
      v. Do not look directly at burning pyrotechnics.
      vi. Do not attempt to extinguish burning explosives, pyrophoric materials, or pyrotechnic mixtures as this can cause an explosion.
10. White Phosphorus (WP):
   a. Hazard: Applies to munitions containing white phosphorus (WP).
      i. WP immediately ignites upon contact with the environment producing dense white smoke.
      ii. The smoke produced by WP is extremely toxic.
      iii. If starved of oxygen, a crust forms over the material. When this crust is broken, WP will immediately reignite.
      iv. If a WP munition is smoking or burning, expect a high-order detonation as WP burns at temperatures higher than the detonating temperature of bursting charge explosives.
   b. Actions: Do not disturb crusted over WP. If WP or RP is burning:
      i. Do not inhale the smoke and move away in an upwind direction.
      ii. Establish an exclusion area in accordance with the "Chemical" safety precaution.
      iii. Never approach a burning or smoking munition.
      iv. Expect a higher-order detonation.
      v. Do not attempt to extinguish burning WP.
11. Cocked Striker (C/S):
   a. Hazard: Unintentional initiation.

A C/S is a firing pin under spring tension, held in place by a positive block within the fuzing mechanism. During fuze arming and functioning, the positive block should have moved allowing the firing pin to function the fuze, but this process was somehow disrupted.

In some fuzes, the detonator versus the pin is the moving component and classified as a "cocked detonator." C/S is applied to these configurations as the same functioning principles apply.

b. Actions: Do not move the munition.

12. Wait time (W/T):
    a. Hazard: Unexpected initiation.

       Applies to fuzes and components containing batteries, capacitors, pyrotechnic, or clockwork mechanisms that provide time delays ranging from milliseconds to years, before functioning.

    b. Actions: When a fuze containing a pyrotechnic, clockwork (C/W), or electronic self-destruct (S/D), or delay function feature is recognized, STOP. There are required wait times (W/T) that need to be researched before further actions are taken.
13. Proximity or Variable Time (VT):
    a. Hazard: Unintentional initiation.

       VT refers to fuzes with electronic sensors allowing them to "see." The sensing element determines distance or proximity to a target, then functions at the desired distance as an airburst. Applies to fuzing incorporating VT, infra-red (IR), old TV guidance systems, and other fuzes with similar sensing capabilities.

       These fuzes usually sustain severe damage upon impact. But some missiles have VT fuzing elements on the side for high-speed aircraft.

    b. Actions:
       i. Approach at a 45° angle from the rear.
       ii. Do not move in front of a VT element that may "sense" you as the intended target and function.
       iii. Also adhere to W/T, EMR, and Static safeties.
14. Piezoelectric (PE):
    a. Hazard: Unintentional initiation.

       PE fuzing uses quartz crystal to produce electric current when stressed that initiates an electric detonator in the fuze. PE crystals constitute a power source with an indefinite shelf life.

    b. Actions:
       i. Do not stress a PE element.
       ii. PE fuzing systems are commonly used with HEAT munitions. Also adhere to EMR, static, and jet precautions.

15. Booby-Trap (B/T):
    a. Hazard: Unintentional initiation.
       B/Ts can be internal or external, mechanically, or electrically functioned.
    b. Actions: Assume all landmines are booby trapped and do not move a munition suspected of containing a booby-trap.
16. Influence:
    Covers magnetic, acoustic, and seismic fuzing systems used with some landmines, bombs, and underwater ordnance.
    (1) Magnetic:
        a. Hazard: Unintentional initiation.
           Magnetic fuzing senses ferrous metal and functions when specific thresholds are met.
        b. Actions: Attempt to identify the munition at distance with binoculars. If magnetic fuzing is identified, do not approach the munition.
    (2) Acoustic:
        a. Hazard: Unintentional initiation.
           Acoustic fuzing senses sounds and functions when specific thresholds are met.
        b. Actions: Attempt to identify the munition at a distance with binoculars. If acoustic fuzing is identified, do not approach the munition.
    (3) Seismic:
        a. Hazard: Unintentional initiation.
           Seismic fuzing senses vibrations in the ground, air, or water and functions when specific thresholds are met.
        b. Actions: Attempt to identify the munition at a distance with binoculars. If seismic fuzing is identified, do not approach the munition.

Step 7: Identify the Munition:

Return to the safe area utilizing the same route taken upon approach. Using the information obtained during approach, inspection, and egress; consult military manuals, historical ordnance literature, and military EOD. Validate findings and attempt to conclusively identify the munition.

Given the number of variables associated with ordnance, it is impossible for any process to be infallible. Because of this, even the most experienced practitioner must be cautious when considering a conclusive identification.

Other considerations that may affect a conclusive identification include:

1. Damage from high-speed impact, fire, and other insult.
2. Deterioration, exposure to the elements.

3. Illegal modifications made after leaving military control.
4. If present, color codes and painted markings are helpful. But repainting after leaving military control, as well as an international history of unpublished or constantly changing color schemes, may render this information useless.
5. Cultural aspects of design are helpful and may include unique shapes, painted, or stamped symbols, or uncommon components.

Closing

Ordnance is inherently dangerous, more so when it has been deployed, damaged, deteriorated, or modified in any way. Adhering to these safety precautions throughout the seven-step identification process, allows additional information to be obtained while working in the safest manner possible. Accurate identification of an unknown munition is the best way to avoid a disastrous outcome. Until proven otherwise, always consider a deployed, damaged, or modified munition to be armed, and in its most hazardous condition.

Fundamentals of Fuze Functioning

3

For 200 years we have been treading so closely in the footsteps of precedent that the ordinary time-fuze of 1855 scarcely differs in principle of applying a composition to graduate and convey a flame to the charge of a shell from that in vogue at Dale in 1632.

Commander John Dahlgren, United States Navy, 1856

Introduction

Commander Dahlgren's observations were accurate but came at a pivotal time in military ordnance development. Until the mid-1800s, advancements in ordnance and fuzing system designs were minimal as the weapon systems and tactics they supported remained largely unchanged. The mid-nineteenth century's industrial revolution resulted in rapid advancements in manufacturing that were quickly applied to ordnance designs. The only element missing was a large-scale opportunity to field-test these new ideas. Throughout the 1840s and 1850s, the Mexican–American War, Crimean War, and other conflicts around the world had little impact on ordnance designs since battlefields were far removed from the scientists, engineers, and manufacturers involved in developing the next innovative ordnance designs. All of that changed with the onset of the American Civil War. Suddenly an opportunity arose to develop and immediately test new weapons and ordnance designs on a massive scale as the two largest armies in the world clashed on their own soil. Many technological advancements from this period are still evident in munition designs today, most notably complex fuzing schemes that maximize functionality and reliability.

What Is a Fuze?

The fuze functions as the brain of a munition. When deployed, the fuze arms and determines when and how the munition will function. Prior to deployment, a fuze must be in a safe condition in order for personnel to handle, transport, and employ the munition without it prematurely functioning.

Whether a fuze was designed in the nineteenth or twenty-first century, its effectiveness is determined by three fundamental principles:

1. **Functionality:** The fuze must contain all the components to reliably initiate the munition.
2. **Precision:** The fuze must function at precisely the right time to ensure maximum effectiveness. In this context, three or four milliseconds can be the difference between success or failure of the munition to perform with maximum efficiency.
3. **Dependability:** When properly deployed, a fuze should arm and function as designed, and must have low failure or "dud" rates to be considered dependable.

The fuzes used today are extremely well engineered and function with unprecedented precision, yet many still fail to function correctly. Common causes of malfunctions include improper predeployment preparation, incorrect deployment, a disruption during deployment, deterioration of components, improper interaction or impact with the target, and material defects in fuzing components.

Function as Designed

To better understand fuzing systems, it is important to discuss the four distinct phases or conditions of a correctly deployed fuze. These are:

1. Safe
2. Committed
3. Arm
4. Final action or function as designed

Prior to functioning as designed, a fuze must move through the safe and committed phases to arm. To accomplish this, fuze designs apply the actions associated with deployment to the arming process. Depending on the delivery system, arming can involve the removal of pins or wires; violent deceleration or "retardation;" slow deceleration or "creep;" violent acceleration "setback;" spin induced centrifugal force; a surge or trickle of electrical power; or mechanical arming vanes that spin as the fuze moves through air or water. Arming a fuze involves a sequence of actions prior to, during, and sometimes after munition delivery, that coincides with the method of delivery, fuzing design, and the intended target.

As a fuze leaves the "safe" condition, it continues the arming process until reaching a point where the process cannot be stopped. This point of

no return is referred to as being "committed." Many fuzes require a combination of three distinct actions to go from safe to armed. Once armed, a munition should function as designed or carry out its "final action," thus functioning the munition.

When ordnance does not function as designed, its condition must be determined. To accomplish this, the phase the fuze was in when the process was interrupted must be ascertained. Conditions represent more specific breakdowns of the four-phases and include safe, partially armed, armed, or unknown. As ordnance is inherently dangerous, any munition that has been deployed and failed to function, is damaged, or its condition cannot be determined is considered "armed" and in an extremely hazardous condition.

Some fuzes are specifically designed to appear benign but are actually boobytraps. Positive identification is required to ensure fuzes with anti-disturbance, self-destruct, lengthy time delays, and other hazards are handled correctly.

Merging Philosophies and Copy-Cats

One fundamental problem with accurately identifying a fuze arises from merging philosophies, supported by varying manufacturing capabilities. Resulting in fuzes made in different countries being identical on the exterior, but with substantial internal differences, as well as different operational functions. When attempting to identify ordnance, virtually everything is critically important. "Everything" includes construction features, materials used, stamped and stenciled markings, paintings, packaging, and all observable characteristics.

Some countries apply a commonsense approach to fuze manufacturing and concentrate on proven designs while others do not. Consider this quote from 1968:

> The aircraft gun fuzes appear to have been based on WWII German types of proven reliability. In some instances, exact copies of internal elements have been noted. In other cases, German mechanical principles have been assimilated with Soviet munition philosophy design practices, resulting in a composite but highly effective design.
>
> **(Fuzes in Vietnam, September 23, 1968)**

When researching ordnance, it is important to always keep copy-cat designs in mind. The practice of one country copying the designs of another complicates accurate fuze identification; but accurately identifying the specific fuze and its condition is required before a safe course of action can be determined.

Fuze Locations Explained

As with all technical disciplines, there are lexicon differences between specific fields that can lead to confusion. When researching ordnance, specifically the location of a fuze, different terms are applied in air and ground ordnance references. For example, an air-delivered bomb defines a fuze in the front as a "nose fuze" and a fuze in the rear as a "tail fuze" (Figure 3.1). A fuze installed in the side is defined as a "transverse fuze" (Figure 3.2). In contrast, a projectile fired from artillery defines a fuze in the front as a "point fuze" and a fuze in the rear as a "base fuze" (Figure 3.3). Fuzes located inside a munition are referred to as "internal" fuzing (See Appendix A, Logic Tree 3).

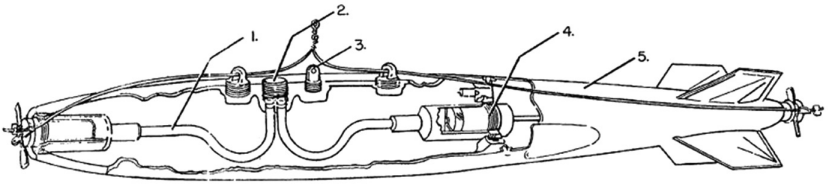

Figure 3.1 (1) Internal electrical plumbing connects the nose and tail fuze wells. (2) Electrical connection or charging port, also connects to both fuze wells. (3) Hoisting lug. (4) Tail fuze well. (5) Conical fins. (From U.S. Military TM.)

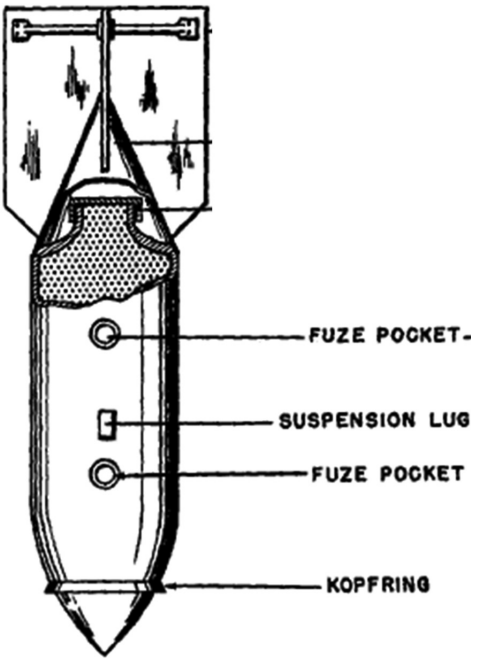

Figure 3.2 Transverse fuzing in a German WWII-era bomb. (From U.S. Military TM.)

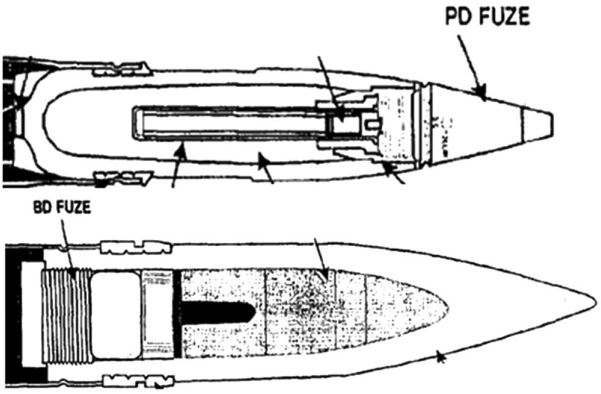

Figure 3.3 Point and base fuzing in a projectile. (From U.S. Military TM.)

These and other terms are important to understand as they define fuzing groups and types. For example, if searching for a "base" versus "tail" fuze in a bomb, the results will be poor as relevant open-source literature and military publications use the term "tail." Due to the infrequent use of transverse fuzing, it is specifically addressed in section 8 of this chapter. Additional lexical nuances are addressed in Chapters 4 through 14 and the appendices.

The Seven-Step Practical Process Applied to Fuzes

Whether a fuze is recovered by itself, on a piece of ordnance where it can be observed, or inside a munition where it cannot, the fuze is always inspected as a stand-alone threat. A fuze itself, presents a threat and larger fuzes contain substantial amounts of high explosive. If installed in a munition, the fuze is capable of functioning it as designed and must be accurately identified.

Category, Fuze:

The fuze category applies whenever a fuze is present, either installed in a munition, or by itself. Under the fuze category are groups and types defined by function and location in a munition. If the category and group of the ordnance can be determined, many possible fuzing configurations can be eliminated, thus greatly reducing the possibilities and increasing the probability of an accurate identification.

A fuze may be capable of functioning a munition during initial approach. Thus, it is critical to attempt to identify the fuze from a safe distance before approaching unknown ordnance.

The Seven-Step Practical Process—Fuze

Step 1: Gather Information, Approach and Initial Inspection:

Attempt to identify from a safe distance with binoculars. Approach at a 45° angle from the rear, avoiding venturis and fuze sensing elements.

Systematicity work from one end of the munition to the other. With a camera and scale, document the length and width of each visible fuze component, as well as the overall fuze, evidence of tampering, modification, impact damage, materials, colors, distinct construction nuances, and stamped or stenciled markings; including the fuze type, model, settings, or lot number (Figure 3.4).

Step 2: Determine Fuze: Group, Type, and Condition: (Appendix A, logic tree 3).

1. Deployed and failed to function, condition is "armed."
2. Missing pins, vanes, clips, collars, wires, other arming components, condition is "armed."
3. Sustained impact damage, condition is "armed."
4. Evidence of tampering or modification, condition is "armed."

Step 3: Determine Ordnance Category: (Appendix A, logic tree 3). The category "fuze" is covered throughout this chapter.

Step 4: Determine Ordnance Group:

The identifiable characteristics associated with each fuze group are covered throughout this chapter.

Step 5: Determine if Munition was Deployed:

Inspect the fuze for impact-related damage, missing pins or clips.

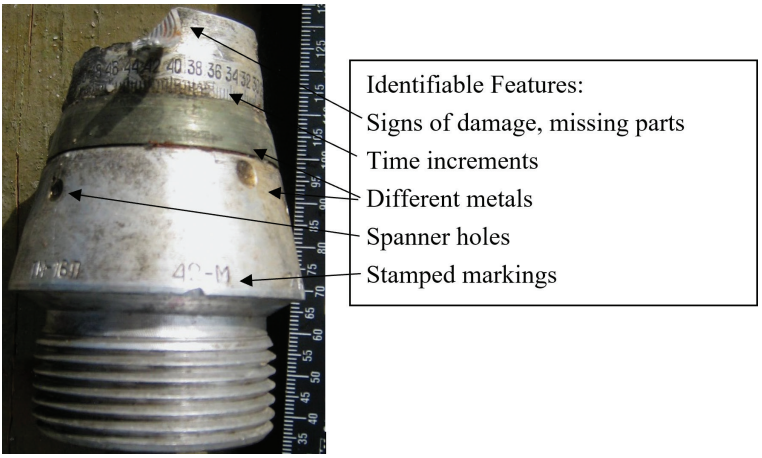

Figure 3.4 Damaged fuze. Identifiable features include stamped markings, different materials, set screws and spanner holes. (Author's photographs.)

If installed in a munition, inspection of the munition will help make this determination.

Step 6: Determine Safety Precautions:

The safety precautions for each fuze group are covered in this chapter. Once identified, these precautions must be adhered to.

Step 7: Research Literature and Identify the Munition:

Apply the totality of measurements, color codes, stamped markings, and construction features to determine the group, and positively identify the fuze. Internal and unidentifiable fuzes are treated as the most hazardous possibility until proven otherwise.

Fuze Groups and Type

There are eight distinctly different fuze "groups" and twenty significantly different fuze "types" covered in this chapter. The primary focus is on the identifying features and safety precautions associated with each group and type. It is important to mention that these groups, types, identification features, and safety precautions covered are in no way all-encompassing as it is impossible to cover all fuzing nuances.

The fuzing groups and types covered are:

1. **Impact**
   a. Point Detonating (PD)
   b. Base Detonating (BD)
   c. All-ways-acting
2. **Point-Initiating Base-Detonating (PIBD)**
   a. Electrical
   b. Mechanical
3. **Time**
   a. Powder Train Time Fuze (PTTF)
   b. Mechanical Time (MT)
   c. Electronic Time (ET)
   d. Clockwork (C/W), short and long delay
   e. Chemical delay
4. **Variable Time (VT) or Proximity**
   a. Active VT
   b. Passive VT
5. **Pressure**
   a. Direct pressure
   b. Pressure/tension release
   c. Hydraulic pressure
   d. Barometric pressure
   e. Hydrostatic pressure

6. **Influence**
   a. Magnetic
   b. Acoustic
   c. Seismic
7. **Anti-Disturbance (A/D)**
8. **Transverse**

Groups and Types

The category is "fuze." The remainder of this chapter covers the fuze groups and types in the following format. Using the group and type, numbers, and letters above, each group will follow the format shown in Number 1.

1. Category: Fuze. Group: Impact: Are designed to function upon impact with a target. There are electrical and mechanical versions capable of functioning instantaneously upon impact or after a delay. Measured in milliseconds, delay features are designed to allow a munition to penetrate a target or pass through treetops prior to functioning.

Depending on design, impact fuzes can be located in the front, rear, side, or inside a munition. There are numerous configurations incorporating a variety of mechanical and/or electrical arming actions that must be performed in the correct sequence. These include pins or wires that must be removed; retardation, setback, or centrifugal force requirements; electrical power or mechanical arming vanes that must rotate to align components. The hazards associated with impact fuzes vary. As with all fuzes, positive identification is required to ensure appropriate safety precautions are applied.

Five fuze types are covered under the impact group.

1.a. Group: Impact. Type: Point Detonating (PD): Used in the nose or front of bombs, projectiles, rifle grenades, projected grenades, rockets, missiles, submunitions, and underwater ordnance. Designed to function upon impact with a target. When deployed, positive identification may be complicated by damage incurred upon impact (Figure 3.5).

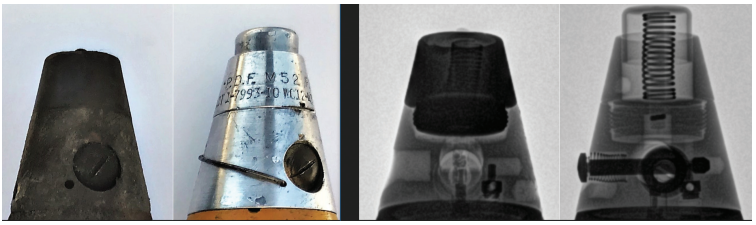

Figure 3.5 U.S. M52 fuze. Portable x-ray is a valuable tool for inspecting the internal components of ordnance fuzing. Note the bore-riding pin missing from the armed fuze on the left, which is secured in the unfired fuze on the right. (Courtesy of Kristin Lejeune.)

General identification features (Figure 3.6):

Materials and Appearance: Steel, aluminum and Bakelite plastics are common. Older fuzes and those made for naval ordnance are often made of brass.

Markings: Nomenclature may be on observable sections.

Other Characteristics:

- Selector lever resembling a standard screw with "D" for delay and "SQ" for super-quick, or similar markings relevant to the country of manufacture.
- A firing pin may be enclosed in the forward end under a cap or closure disk.
- On older designs, the firing pin may protrude from the forward end of the fuze.
- Many PD fuzes in bombs, missiles, and underwater ordnance are completely covered by a penetrator, plug, guidance section or shroud and are not externally visible.
- A viewing window displaying a color associated with the condition of the fuze is present on some bomb fuzes.

General Safety Precautions:

- HE, frag, movement.
- C/S for some PD fuzes.
- EMR, static, W/T for fuzes with electrical components.

Figure 3.6 Example of various shapes and sizes of point detonating (PD) fuzes. Top, left to right: Chinese 122, U.S. M567, M524, M557, M739A1, Chinese M12 and MJ-1. Bottom, left to right: Russian RGM-2, Yugoslavian UTM-94, U.S. M527, Yugoslavian UTPE-M69 and UTM68, and Russian M6. (Courtesy of Daniel Evers.)

1.b. Group: Impact. Type: Base Detonating (BD): Used in the base or aft-end of bombs, projectiles, rifle grenades, rockets, missiles, submunitions, and underwater ordnance, as well as anti-tank hand grenades. Designed to function upon impact with a target. Unlike fuzes located on front of a munition, base fuzes are protected from direct impact and usually undamaged. Yet when deployed, identification is often complicated as many BD fuzes are installed flush with the base of a munition, or covered by fins, a tracer element, rocket motor, or other components.

General identification features (Figures 3.3 and 3.7):

Materials and Appearance: Steel, aluminum, and Bakelite plastics are common. Older fuzes and those made for naval ordnance are often made with brass, some with very high copper content resulting in a "reddish" color. Tracer elements and other components block direct observation making it impossible to determine if a fuze is installed underneath.

Markings: Nomenclature may be on observable sections.

Other Characteristics:

- Spanner holes in the base of a munition may indicate the presence of a fuze, flush with the munition body.
- Wrench flats on protruding portions of the fuze.
- Many BD fuzes are completely covered and not externally visible.
- A viewing window or other means of displaying a color associated with the arming condition of the fuze may be present on some bomb fuzes.
- Found in APHE and HEAT munitions.

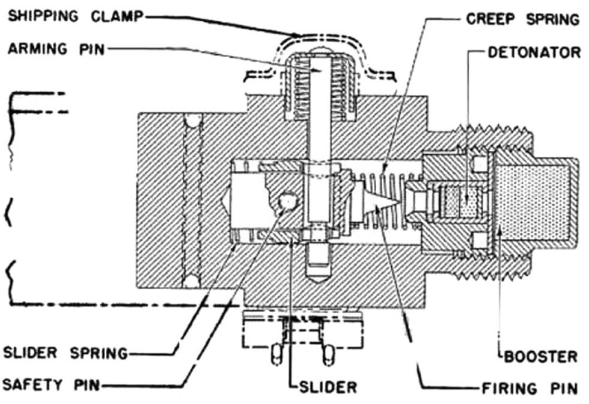

Figure 3.7 M401 BD fuze from a U.S. 3.5in (89mm) HEAT Rocket. See Chapter 5, Section 2. (From U.S. Military TM.)

General Safety Precautions:

- HE, frag, movement.
- C/S for some BD fuzes.
- EMR, static, W/T for fuzes with electrical components.

1.c. Group: Impact. Type: All-Ways-Acting: Used with ordnance deployed without a means of stabilization. As the orientation at time of impact cannot be predetermined, a fuze capable of functioning at all possible angles is required. When deployed, identification may be difficult as these fuzes are oftentimes completely inside the munition.

General identification features:

Materials and Appearance: Steel and aluminum are most common.

Markings: No markings are common on these fuzes.

Other Characteristics:

- The lack of stabilization on a munition such as rotating band, slanted venturis, fins, ribbon, or parachute is an indicator of an all-ways-acting fuze.
- Mechanical versions may use arming vanes, which can detach after arming the fuze.
- Electrical versions will have contacts or an electrical umbilical connector.
- Suspect an internal all-way-acting fuze if a munition has explosives-related color codes or markings but lacks an observable fuze or recognized means of functioning.
- Used in firebombs, impact fuzed hand grenades, and submunitions.

General Safety Precautions:

- HE, frag, movement.
- EMR, static, W/T for fuzes with electrical components.

2. Category: Fuze. Group: Point-Initiating Base Detonating (PIBD): Consists of two separate fuzing components that must work in conjunction to function the munition correctly. A point-initiating (PI) element in the point or nose of the munition works similarly to a PD or a VT fuze. The base detonating (BD) element in the base or tail of the munition acts in a similar manner as a stand-alone BD fuze.

PIBD fuzes are designed to function in close proximity to, or upon impact with a target. There are numerous designs including PI elements that are completely covered and unobservable, and many that mimic the appearance of PD or VT fuzing. When deployed, positive identification of the PI element is often

difficult due to damage incurred upon impact. The BD element in the rear is protected from direct impact, but may be covered by fins, a tracer element, a rocket motor, or be completely internal, thus complicating identification. There are two distinctly different PIBD designs, electrical and mechanical.

2.a. Group: PIBD. Type: Electrical: Used in bombs, projectiles, hand grenades, rifle grenades, rockets, missiles, submunitions, and underwater ordnance. Designed to function when the PI element provides the required electrical energy to the BD element during flight or upon impact with a target. There are three common electric PIBD configurations.

1. A wire is used to electrically connect the piezoelectric crystal in the PI element to the BD element, as seen in Figure 3.8. Other configurations incorporate an internal liner as the conduit connecting the PI and BD elements. Upon impact, the electricity produced by the PE crystal will function the BD element.
2. Crush switched incorporate an inner and outer shell that complete a circuit when they touch. Upon impact, the outer shell is crushed against the inner shell, completing the circuit and functioning the BD element.
3. A VT or other sensing element in the nose sending an electrical signal to the BD element at the precise time for it to function (Figure 3.1).

Figure 3.8 U.S. M409, 152mm HEAT projectile. (Author's photograph.)

General identification features:

Materials and Appearance: Configurations 1 and 2, range from thick steel to thin aluminum as seen in Figure 3.8. Configuration 3, with a VT or sensing element, will be almost entirely plastic or include plastic components.

Markings: Nomenclature may be on observable sections.

Other Characteristics:

- The PI element may appear to be a standard PD, PTTF or other time fuze configuration.
- Common PIBD fuze designs incorporate graze-sensitive features that may include a cocked-striker (C/S). Graze-sensitive features allow a fuze to function upon a glancing impact with the target. Once armed, fuzes containing this characteristic are extremely sensitive.
- Used with HE bombs, anti-aircraft missiles, underwater ordnance, and HEAT warheads from all categories.

General Safety Precautions:

- HE, frag, movement, PE, EMR, static, and W/T.
- Jet for HEAT munitions.

2.b. Group: PIBD. Type: Mechanical: Used in projectiles, rifle grenades, projected grenades, rockets, submunitions and underwater ordnance. Designed to function when the PI element functions and mechanically provides the energy required to function the BD element via "spitback."

Figures 1.3 and 3.9 show PIBD spitback configurations in which the PI element functions to project a flame (Figure 1.3 Chapter 1) or ballistic disk (Figure 3.9) rearward, passing through the hollow section of the warhead to initiate the BD element, allowing the munition to function as designed.

General identification features:

Materials and Appearance: Range from thick steel to thin aluminum. The PI element may appear to be a standard PD, PTTF or other time fuze configuration.

Markings: Nomenclature may be on PI element.

Other Characteristics:

- The PI element may appear to be a standard PD, PTTF or other time fuze configuration.
- Common PIBD fuze designs incorporate graze-sensitive features that may include a cocked-striker (C/S). Graze-sensitive features allow a fuze to function upon a glancing impact with the target. Once armed, fuzes containing this characteristic are extremely sensitive.

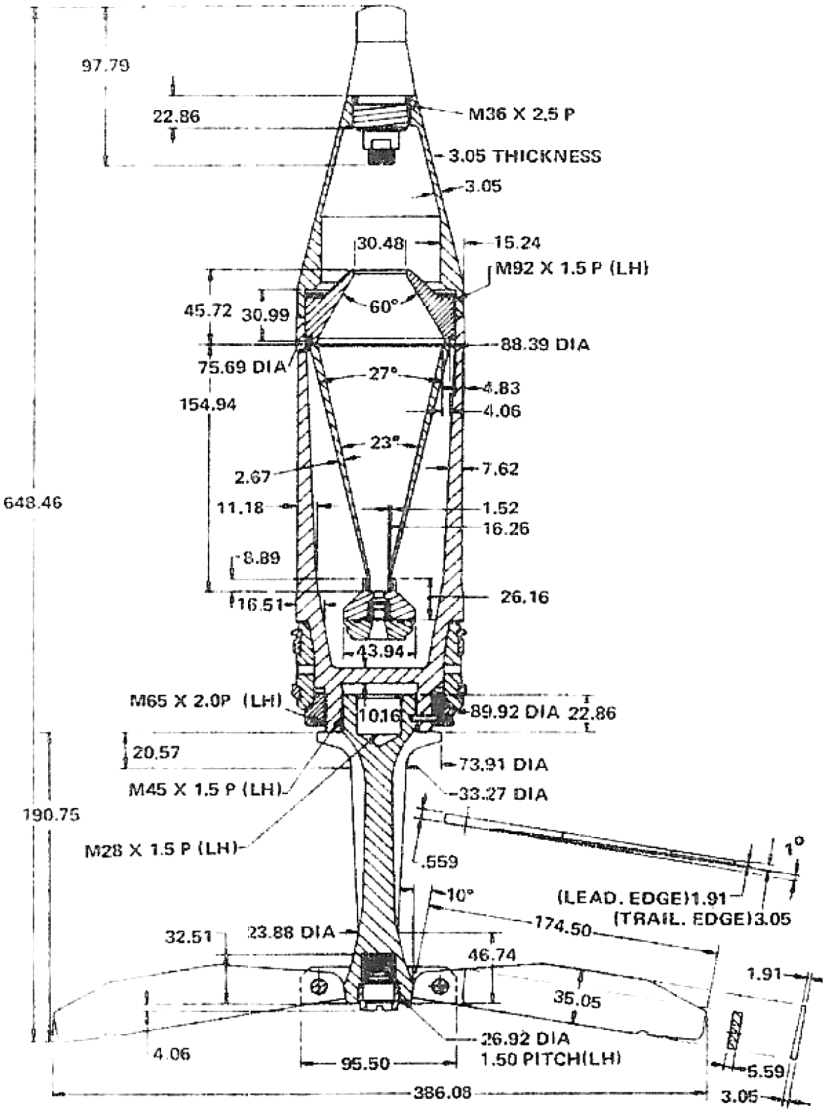

Figure 3.9 Russian ZBK-5M, 100mm (3.9in) HEAT projectile. (From U.S. Military TM.)

- Used with HE bombs, anti-aircraft missiles, shrapnel projectiles, underwater ordnance, and HEAT warheads from all categories.

General Safety Precautions:

- HE, frag, movement.
- Jet for HEAT munitions.

3. Category: Fuze. Group: Time: Are designed to function a munition during deployment or after reaching the target. There are electrical, mechanical, and pyrotechnic time fuze designs that can be located in the front, rear, side, or inside a munition.

Time delays can serve as self-destruct (S/D) backup features to ensure a munition functions if the primary means fail. For example, anti-aircraft artillery (AAA) that does not hit an aircraft, will fall back to earth in close proximity to the people firing it, then detonate. To ensure this does not happen, a time-related S/D feature is used so the AAA will detonate at altitude and rain down in small pieces versus an intact munition. A S/D capability also serves the purpose of greatly decreasing the number of unexploded ordnance (UXO) items on the battlefield that might otherwise impede troop movement.

There are many time fuze configurations incorporating a variety of mechanical and/or electrical arming actions or sequences. These include pins or wires that must be removed; retardation, setback, or centrifugal force requirements; electrical power or mechanical arming vanes that must rotate to align components. The hazards associated with time fuzes vary. As with all fuzes, positive identification is required to ensure appropriate safety precautions are applied.

Five fuze types are covered under the time group.

3.a. Group: Time. Type: Powder-Train-Time (PTTF): Used in the nose, base, or inside of projectiles, rifle grenades, hand grenades, rockets, submunitions, and underwater ordnance. PTTFs are the oldest type of time fuze and contain a black powder train that burns for the set time before functioning the next component of the fuze.

There are two distinctly different powder-train-time (PTT) fuzes. One is the internal pyrotechnic delay commonly used with hand grenades (Figure 3.10). The other is a multi-piece fuze containing numerous black powder delay channels stacked such that one layer burns down to ignite the next until the fuze functions (Figures 3.11 and 3.12). To increase reliability, many PTT fuzes also incorporate an impact feature to function the munition when the time-functioning element fails. When deployed, positive identification is usually possible as most designs withstand impact well. Primary applications include dispensers, shrapnel projectiles, delay element in hand grenades, anti-aircraft ordnance, and pyrotechnic self-destruct features.

It is important to note that PTT fuzing is very common on historic ordnance with black powder main charges. Due to design and appearance differences that evolved over time, this is covered in greater depth in Chapter 13.

General identification features:

Materials and Appearance: Completely brass or at least one brass component containing the black powder train. Arranged in a multipiece-stacked design with vent holes or gaps between layers to allow smoke to escape.

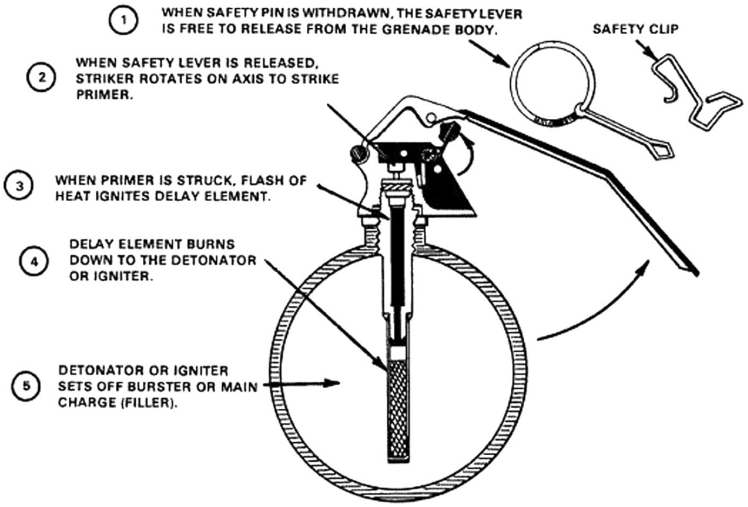
1 WHEN SAFETY PIN IS WITHDRAWN, THE SAFETY LEVER IS FREE TO RELEASE FROM THE GRENADE BODY.
SAFETY CLIP
2 WHEN SAFETY LEVER IS RELEASED, STRIKER ROTATES ON AXIS TO STRIKE PRIMER.
3 WHEN PRIMER IS STRUCK, FLASH OF HEAT IGNITES DELAY ELEMENT.
4 DELAY ELEMENT BURNS DOWN TO THE DETONATOR OR IGNITER.
5 DETONATOR OR IGNITER SETS OFF BURSTER OR MAIN CHARGE (FILLER).

Figure 3.10 U.S. M67 fragmentation hand grenade with Powder Train Delay Element in the Fuze. (From U.S. Military TM.)

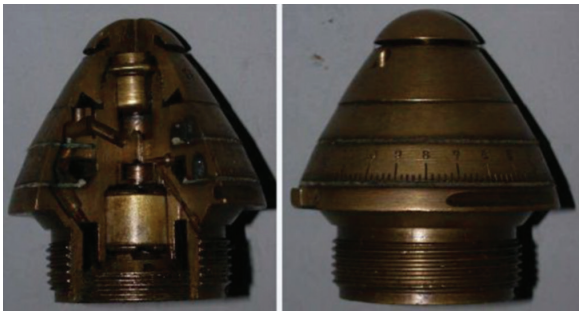

Figure 3.11 U.S. M1907, PTTF. (Author's photograph.)

Figure 3.12 Powder Train Time Fuzes (PTTF). From left: U.S. M84A1 and Model 1907, Chinese MS-3A. (Author's photograph.)

Markings: Timing increments and nomenclature are usually stamped on the fuze.

General Safety Precautions:

- HE, frag, movement, W/T.

3.b. Group: Time. Type: Mechanical Time (MT): Used in the nose, base, or inside projectiles, rifle grenades, rockets, submunitions, and underwater ordnance. Designed to function during flight, or after a preset time has elapsed after impact. To increase reliability, many MT fuzes have an impact backup feature displayed as "Super-Quick" or SQ. When deployed, positive identification is usually possible as most designs withstand impact well. Multiple configurations are displayed in Figure 3.13.

General identification features:

Materials and Appearance: Steel, aluminum and brass are most common. Arranged in a multipiece-stacked design with a time calibration scale. Or a single piece design with viewing window to see the time settings.

Markings: Timing increments and nomenclature are usually stamped on the fuze. MT fuzes on flechette munitions may have calibration scale settings in meters to allow a desired distance to be set.

Other Characteristics:

- Setting lugs or slots to accommodate specific tools used to set the fuze.
- SQ feature to function fuze on impact.
- Used in dispensers, flechette munitions, anti-aircraft ordnance, and as a self-destruct feature.

Figure 3.13 Mechanical Time (MT) fuzes for projectiles. From left, U.S. MK51 MOD 4, Russian VM-30 Series, U.S. M577, M565, M772, and M520A1. (Author's photograph.)

General Safety Precautions:

- HE, frag, movement and C/S.
- MT fuzes use a clockwork timing mechanism to release a C/S at the pre-set time.

3.c. Group: Time. Type: Electronic Time (ET): Used in the nose, base, or inside projectiles, rockets, submunitions, missiles, landmines, and underwater ordnance. ET fuzes use electrical power sources to run timing circuits and function an electric detonator. Models vary, but time settings can be made by hand, manually programmed with an electronic fuze setter, or remotely programmed. Designed to function during flight, or after a preset time has elapsed after impact. Many ET fuzes have an impact backup feature. When deployed, positive identification is often difficult due to damage incurred upon impact.

General identification features (Figure 3.14):

Materials and Appearance: Usually an aluminum or composite outer body, with plastic components.

Figure 3.14 M767A1 Electronic Time (ET) fuze with a time calibration window. (Author's photograph.)

Markings: Nomenclature may be on observable sections. A common characteristic of ET fuzes is a complete lack of external marking.

Other Characteristics:

- Many designs are "plugged into" a programing tool and have a bullseye appearance on the nose, or other ringed electronic contact, insulator configurations to accommodate programing.
- May have a digital display, time set viewing window on the body as seen in Figure 3.14.

General Safety Precautions:

- HE, frag, movement, EMR, static, and W/T.

3.d. Group: Time. Type: Clockwork (C/W) Short and Long-Delay: Used in the base or side of bombs, submunitions, and underwater ordnance. Unlike other time fuzes, long-delay fuzes are designed as area denial munitions. C/W long-delay fuze mechanisms are capable of setting options ranging from a few minutes to a few months. For example, the MK346 in Figure 3.15 can be set for a few minutes to 660 hours. To prevent successful EOD countermeasures, most long-delay designs include an anti-withdrawal feature to function the fuze if removal is attempted.

General identification features:

Materials and Appearance: Completely metal. Designed to look like other conventional, relatively safe fuzing.

Markings: Nomenclature may be on observable sections.

Other Characteristics:

- Time delay is set prior to fuze installation and the time set viewing window is usually inside the munition when deployed.
- Designed to look like benign or simplistic fuzing.
- Incorporate anti-withdrawal devices to kill unwary operators. Positive identification is crucial.
- Used with HE bombs and submunitions.

General Safety Precautions:

- HE, frag, movement, C/S, and W/T.
- The clockwork timing mechanism releases a C/S at the preset time.

3.e. Group: Time. Type: Chemical Delay: Used in the base of bombs. Designed as area denial munitions. C/W long-delay fuze mechanisms are capable of setting options ranging from a few minutes to a few months. For example, the M123 fuze in Figure 3.16 can be set from minutes to 144 hours.

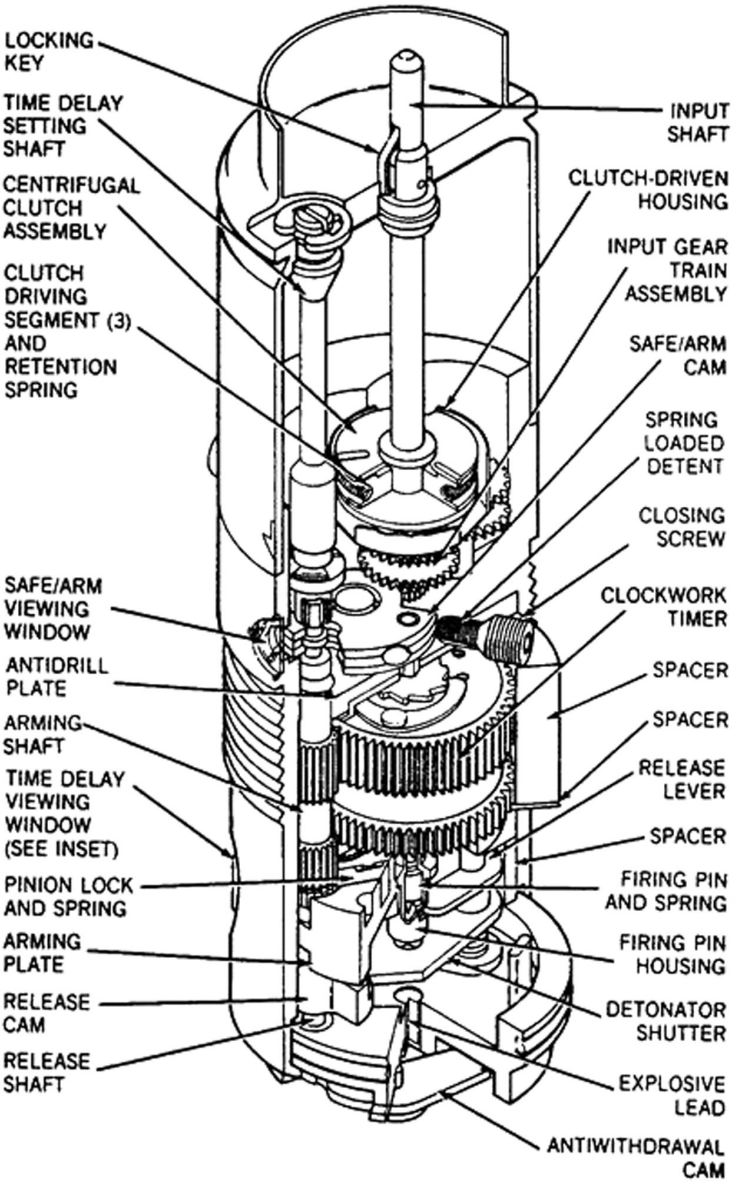

Figure 3.15 MK 346 Clockwork (C/W) long delay fuze. Note the "Antiwithdrawal Cam" near the base. (From U.S. Military TM.)

To prevent successful EOD countermeasures, most long-delay designs include an anti-withdrawal feature to function the fuze if removal is attempted.

Prior to installation, the desired time delay and temperature at the target site must be known; these are used to determine which ampule to install. When deployed, the ampule is broken, allowing the caustic liquid to begin

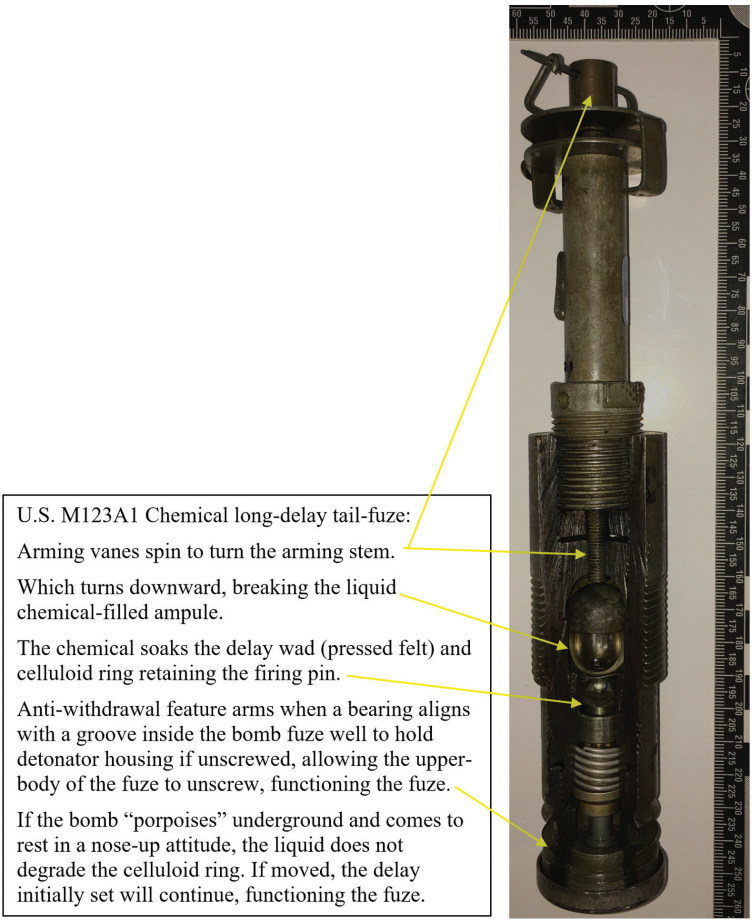
U.S. M123A1 Chemical long-delay tail-fuze:
Arming vanes spin to turn the arming stem.
Which turns downward, breaking the liquid chemical-filled ampule.
The chemical soaks the delay wad (pressed felt) and celluloid ring retaining the firing pin.
Anti-withdrawal feature arms when a bearing aligns with a groove inside the bomb fuze well to hold detonator housing if unscrewed, allowing the upper-body of the fuze to unscrew, functioning the fuze.
If the bomb "porpoises" underground and comes to rest in a nose-up attitude, the liquid does not degrade the celluloid ring. If moved, the delay initially set will continue, functioning the fuze.

Figure 3.16 U.S. M123A1 Chemical long-delay tail-fuze. (Author's photograph.)

degrading the positive block retaining the C/S. Differing acidic strengths of the ampoule liquids and temperature dictate reaction times and are used to set functioning times. To prevent successful EOD countermeasures, these fuzes include anti-withdrawal features to function the fuze if removal is attempted.

The arrival of long-delay MT and ET fuzing render these obsolete. However, if the bomb "porpoised," or turned nose-up after impacting the ground, the liquid will not react with the C/S retainer until moved. In 2011, three German EOD technicians were killed and two injured when a dud U.S. bomb with a M123 fuze they were about to start working on at a construction site detonated. In 2016, a U.S. Marine EOD technician encountered an M123 fuzed bomb during a Humanitarian Mine Action (HMA) mission in Laos. These incidents provide evidence that these fuzes will continue to be encountered and pose significant hazards.

General identification features:

Materials and Appearance: Completely metal. Designed to look like other conventional, relatively safe fuzing. There may be a copper component where the ampoule sits. Positive identification is crucial.

Markings: Nomenclature and time delay setting may be on observable sections.

Other Characteristics:

- Time delay is configured prior to fuze installation.
- Designed to look like benign or simplistic fuze.
- Incorporate anti-withdrawal device to kill unwary personnel.

General Safety Precautions:

- HE, frag, movement, C/S, W/T.

4. Category: Fuze. Group: Variable Time (VT) or Proximity: Referred to as "VT" fuzes in this text. The fuze interprets electronic signals and functions at a specific distance or proximity to the target. Designed to function as an airburst, VT fuzing maximizes munition effects, and most designs incorporate an impact backup feature.

Initially fielded in the early 1940s, many power sources have been used in VT fuzes. The wet power cells in early designs such as the MK58 seen in Figure 3.17, were replaced with dry cell batteries and capacitors charged by wind-driven generators seen in Figure 3.18. Some early designs had a loop-antenna appearance as seen in Figure 3.19.

Over the last 75 years, materials used to make these fuzes, as well as the tactical applications, and overall technology associated with VT fuzing has evolved. The results are many typical and atypical fuzing designs, involving different mechanical and electrical arming actions or sequences. These actions or sequences include pins or wires that must be removed, setback and centrifugal force requirements, travel time through air to allow arming vanes to rotate, and electrical surge or trickle charge to power electronic packages, sensors, and ultimately function the fuze.

There are two ways VT fuzes work, both share the same identifiable characteristics:

1. **Active VT:** Electronics produce and receive active signals reflecting off the target. When the return time equates to a specific distance or proximity to the target, thus matching the fuze settings, it functions.
2. **Passive VT:** Electronics interpret heat and sound signals from the target, match them to the fuze setting, and function when the target and setting match.

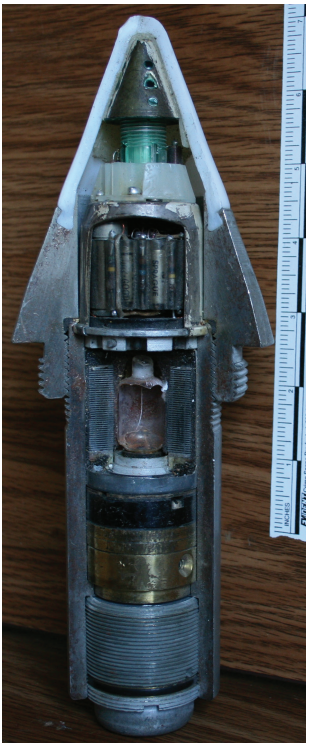

Figure 3.17 U.S. MK58 VT fuze with wet cell power source. (Author's photograph.)

Figure 3.18 Different fuze configurations with a VT capability. Top row, left to right: U.S. M517, M532, British L116A1, U.S M732A2. Bottom row: Russian M80, U.S. M734, and Norwegian PPD323. (Courtesy of Dan Evers.)

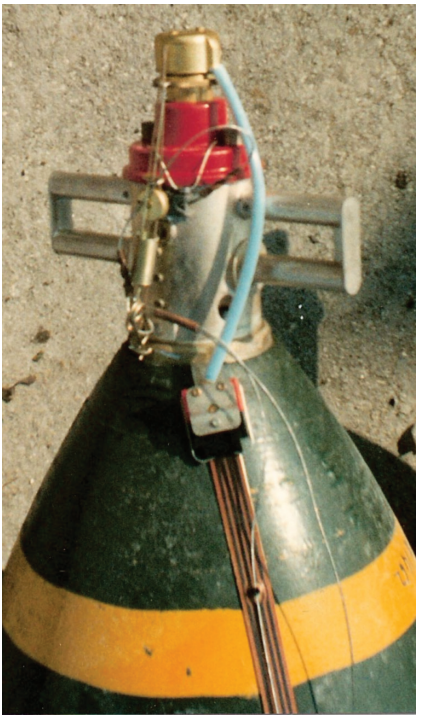

Figure 3.19 British No 952 MK1, VT fuze. (Author's photograph.)

There are three commonly used VT fuze configurations:

1. Single-Element Fuze: A multi-piece fuze located in the nose or front of a munition. All the components required to operate and function the munition are contained in this fuze.
2. Two-Element Fuze: A multi-piece, multi-element fuze. A common configuration is a proximity-sensing element in the nose or front of the munition that is electrically connected to a base or tail element containing the remaining fuze components, as seen in Figure 3.1.
3. Side-Mounted Fuze: A common design on high-speed anti-aircraft missiles that need to "see" a broader field to counter the speed and turns aircraft will employ to evade the missile. These fuzes have sensors configured in long narrow strips running down the side of the forward-end of the missile, and usually work in sync with a forward-mounted sensing element.

General identification features:

Materials and Appearance: Older designs used with bombs and large rockets were made of steel or other metals in the shape of a "T" or

loop as seen in Figure 3.19. Most projectile, designs have maintained the appearance of the fuzes in Figure 3.18.

- Plastic components are a reliable key identifying feature for VT fuzing (Figures 3.18 and 3.19).
- Plastic components can be opaque, translucent, or a number of colors.

Markings: Nomenclature may be on observable sections and some VT fuzes have graduated time rings

Other Characteristics:

- VT fuzes with graduated time rings like those on MT fuzing, allow settings to be adjusted in the field.
- If no setting options are present, it means the fuze will function at a predetermined distance from the target.
- There are multi-option VT fuzes with settings for proximity airburst, impact, or impact delay, such as the M734 in Figure 3.18.
- Used with bombs, projectiles, rockets, and missiles.

General Safety Precautions:

- HE, frag, movement, VT, EMR, static, and W/T.
- There are VT fuzes with C/S impact backups.
- Always considered to be actively seeking targets until proven otherwise.

5. Category: Fuze. Group: Pressure: Are designed to function when specific pressure requirements are met. There are electrical and mechanical versions that can be located on the front, top, rear, bottom, or inside a munition.

There are numerous designs incorporating a variety of mechanical and/or electrical arming actions that must be performed in the correct sequence. Most commonly associated with landmines, boobytraps, and underwater ordnance, most pressure fuzes are deployed by being placed versus fired or dropped. As such, common arming actions include pins, wires or clips that must be removed, or electronic components that must be powered or programmed. As with all fuzes, positive identification is required to ensure appropriate safety precautions are applied.

Five fuze types are covered under the pressure group.

5.a. Group: Pressure. Type: Direct: The most common fuzing used in landmines, boobytraps and underwater ordnance. Designed to function when enough pressure is applied to move a positive block and free a firing pin, or to overcome a coiled or Belleville spring driving a firing pin into the detonator.

General identification features:

Materials and Appearance: Metal and plastic bodies with rubber coverings are common. A "push-plate" or prongs are common on mines.

Markings: Nomenclature may be on observable sections.

General Safety Precautions:

- HE, frag, movement.
- EMR, static for fuzes with electrical components.

5.b. Group: Pressure. Type: Pressure/Tension Release: The most common boobytrap fuze used in the secondary fuze wells of anti-tank (AT) mines, and primary fuzing in anti-personal (APERS) fragmentation and bounding fragmentation mines. Designed to function when the pressure applied on an item, or the tension on a trip-line, is released.

General identification features:

Materials and Appearance: Metal or plastic bodies are most common. Mousetrap-like functioning is common, as are prongs or a tripwire running to an anchor point.

Markings: Nomenclature may be on observable sections.

General Safety Precautions:

- HE, frag, movement.
- EMR, static for fuzes with electrical components.

5.c. Group: Pressure. Type: Hydraulic: Used in landmines. Designed to function when enough pressure is applied to move a positive block and free a firing pin, but there is an additional time requirement. The "time" component allows for target specificity; for example, tanks and other tracked vehicles maintain positive pressure on an area for a longer period of time than wheeled vehicles, which is exploited by hydraulic fuzing. Some designs have the ability to count targets and function after a specific number.

General identification features:

Materials and Appearance: Metal, plastic, and rubber.

Markings: Nomenclature may be on observable sections.

Other Characteristics: Tubes or hose-like components may be present.

General Safety Precautions:

- HE, frag, movement.
- EMR, static for fuzes with electrical components.

5.d. Group: Pressure. Type: Barometric: Used in missiles and bombs. Designed to arm or function when specific altitude-related pressures are experienced during assent or descent, and function at a precise altitude. These fuzes are uncommon.

General identification features:

Materials and Appearance: Metal body and parts.

Markings: Nomenclature may be on observable sections.

General Safety Precautions:

- HE, frag, movement.

5.e. Group: Pressure. Type: Hydrostatic: Used in depth charges, depth bombs, signal devices, and other underwater fuzing systems. Designed to arm or function when specific hydrostatic pressures are experienced during assent or descent, and function at a precise depth.

General identification features:

Materials and Appearance: Brass and other metals.

Markings: Nomenclature may be on observable sections.

General Safety Precautions:

- HE, frag, movement.
- EMR, static for fuzes with electrical components.

6. Category: Fuze. Group: Influence: Are designed to function when specific magnetic, acoustic, or seismic thresholds are presented. Influence fuzing systems can be programmed for specific targets, are extremely sophisticated, exemplify the precision aspect of fuze functioning, and are very dangerous.

Depending on design, influence fuzing can be located in the front, rear, side, or inside a munition. Some designs incorporate an external sensor tethered to the munition. Arming actions or sequences can include pins or wires that must be removed; retardation, setback, or centrifugal force requirements; electrical power or mechanical arming vanes that must rotate to align components. After impact or placement on the ground or in the water, the fuze will sync with the environment before completely arming. If the fuze does not function before its tactical or technical lifecycle ends, self-destruct (S/D) features are incorporated to destroy, or complicate efforts to exploit the munition.

An effective tactic is to combine two influence fuzing types in a single fuze. For example, a seismically activated, magnetically functioned fuze can "sleep," thus saving battery power and extending its lifecycle for days or even years. When a tank or other target with the programmed seismic signature

come within range, the fuze "wakes up." Once awake, the magnetic influence feature is ready to go.

Three fuze types are covered under the influence group.

6.a. Category: Influence. Group Magnetic: Used in bombs, landmines, and sea mines. Designed to detect changes in the amount of ferrous metal in the vicinity, and function when those changes match programmed setting.

General identification features:

Materials and Appearance: Plastic and metal, which may be anodized gold. Most designs consist of two or three separate components.

Markings: Nomenclature may be on observable sections. Older U.S. designs cover the entire tail or base of a bomb with a gold anodized plate.

General Safety Precautions:

- HE, frag, movement, EMR, static, influence, and W/T.
- Positive identification from a distance is crucial.
- Always considered as actively seeking targets until proven otherwise.

6.b. Category: Influence. Group: Acoustic: Used in bombs, landmines, and sea mines. Designed to detect new sounds or changes in ambient sounds and function when changes match programmed setting.

General identification features:

Materials and Appearance: Plastic and metal. Most designs consist of two or three separate components, including an arming section, booster, and hydrophone.

Markings: Nomenclature may be on observable sections.

General Safety Precautions:

- HE, frag, movement, EMR, static, influence, and W/T.
- Positive identification from a distance is crucial.
- Always considered to be actively seeking targets until proven otherwise.

6.c. Category: Influence. Group Seismic: Used in bombs, landmines, and sea mines. Designed to detect vibrations caused by low-frequency sound or movement in the vicinity and function when changes match programmed setting. Used to function a munition or activate dormant magnetic fuze components.

General identification features:

Materials and Appearance: Plastic and metal. Most designs consist of two or three separate components, including an arming section, booster, and geophone to detect vibrations.

Markings: Nomenclature may be on observable sections.

General Safety Precautions:

- HE, frag, movement, EMR, static, influence, and W/T.
- Positive identification from a distance is crucial.
- Always considered to be actively seeking targets until proven otherwise.

7. Category: Fuze. Group: Anti-Disturbance (A/D) Fuzing: Are designed to kill those attempting to move the munition and intimidate those nearby. They can be used as a primary or secondary means of functioning. There are electrical and mechanical versions that arm after deployment, and some are disguised to appear as a conventionally fuzed munition.

Depending on design, A/D fuzes can be located in the front, rear, side, or inside a munition and incorporate a variety of mechanical and/or electrical arming actions that must be performed in the correct sequence. These include pins or wires that must be removed; retardation, setback, or centrifugal force requirements; electrical power or mechanical arming vanes that must rotate to align components.

General identification features:

Materials and Appearance: Metal and plastic. Most A/D fuzing is completely internal or in a component that cannot be seen.

Markings: Nomenclature or markings are seldom present.

Other Characteristics:

- Unlike anti-withdrawal features requiring a fuze to be unscrewed or withdrawn, an A/D fuze will function with the slightest movement.
- Commonly used in conjunction with a self-destruct feature.

General Safety Precautions for A/D fuzes include:

- HE, frag, movement, EMR, static, W/T, and B/T.

8. Transverse Fuzing: In order to clarify an oftentimes confusing topic, a brief explanation on transverse fuzing is provided. Transverse is defined as "situated or extending across something." When applied to ordnance fuzing, this means the fuze is located in the side versus either end or internal to the

munition. Thus, transverse is associated with location, not a means of functioning. Due to the specifically limited employment of the location, special mention is made to ensure these fuzes are not missed during inspection, or under-appreciated when assessing potential hazards.

There are mechanical and electrical versions of transverse fuzes capable of functioning upon impact, after short and long delays, as a VT and influence fuze with additional components, and can also incorporate S/D features. They are most commonly used in bombs, missiles, submunitions, landmines, and underwater ordnance.

General identification features:

Materials and Appearance: Usually made with steel, brass, or aluminum. The fuze usually sits flush with or countersunk into the side of a munition and secured with a locking ring.

Markings: Nomenclature may be on observable sections.

Other Characteristics:

- Spanner holes in the visible face of the fuze.
- Electrical contacts on the visible face of the fuze.

General Safety Precautions:

- HE, frag, movement.
- B/T for anti-withdrawal features.
- EMR, static, and W/T for fuzes with electrical components.

Closing

As the brain of a munition, fuzing constitutes the primary threat. When a fuze has been damaged by impact, fire, or other insult, the state of the internal components is unknown. An accurate identification is the best option for learning as much as possible about the fuze, its current condition, safety precautions that need to be applied, and ultimately the best options to mitigate the situation.

Ordnance Category—Projectiles

4

No one accuses the gunner of maudlin affection for anything except his beasts and his weapons. He serves at least three jealous gods—his horse and all its saddlery and harness; his gun, whose least detail of efficiency is more important than men's lives; and, when these have been attended to, the never-ending mystery of his art commands him.

Rudyard Kipling

Introduction

Interestingly, Kipling used the words "mystery" and "art" when describing an artilleryman. The mystery may have been the manner and variety in which the ordnance functioned, and art may have alluded to the accuracy projectiles can attain when fired over great distance. Commonly referred to as the "king of battle," artillery accounts for more combat casualties than any other weapon system, thus making Kipling's choice of words quite insightful.

A projectile is described as a munition propelled by external force and continuing in motion under its own inertia. The first projectiles include stones thrown from a medieval trebuchet to black powder-filled exploding cannonballs to the many different ordnance categories of today.

For this chapter, the defining factors categorizing a munition as a "projectile" are:

1. The object being projected is fired down a barrel or tube by gas pressure generated from a propellant charge.
2. The propellant charge is the munition's primary means of deployment.
3. The object being projected does not have an attached motor, or other primary means of propulsion.

Munitions under the projectile category meeting these three defining factors are fired from mortars, howitzers, recoilless rifles, and guns. There are exceptions to this definition, such as projected grenades which meet all defining characteristics of a projectile but are categorized under grenades. As well as Rocket-Assisted Projectiles (RAP) that have a rocket motor for

secondary propulsion to increase range after the projectile has been fired. See Appendices D and E for information on marking schemes.

Chapter 13 addresses pre-1900 projectiles, whereas this chapter focuses on post-1900. As the original ordnance items requiring its components to be identified, projectile shapes and designs have influenced the naming conventions of all ordnance categories. Many of the construction aspects covered in this chapter will be seen again in the chapters on rockets, missiles, rifle grenades, projected grenades, and submunitions.

Delivery Systems

There are four primary delivery systems used to fire projectiles. Each system fires differently and deploys projectiles on different trajectories for different tactical applications. Projectiles cannot be fired from more than one system, so this becomes a "Type" characteristic and helpful for identifying an unknown projectile.

Mortars: Designed to fire a projectile over a barrier such as a structure or terrain feature in a high-arc trajectory. Some mortar tubes are rifled, but most have a smooth bore.

Howitzers: Constitute the majority of field artillery pieces and fire a medium velocity projectile in a low-arc trajectory. Howitzers normally have rifled bores.

Recoilless rifles: Fire a projectile at high velocity with a flat trajectory. As the name implies, these weapons have no recoil as the energy is blown out of the opposite end of the tube from the projectile. Recoilless rifles normally have rifled bores, but there are smoothbore versions usually classified as recoilless guns.

Guns: Fire a projectile at very high velocity with a flat trajectory. Commonly fired from ships, tanks, and field guns with rifled or smooth bores.

Projectile Configurations

There is a diverse number of projectile designs. The most common configurations can be seen in Figure 4.1:

Fixed: Projectile is crimped and secured to a cartridge case. The propellant charge cannot be accessed or altered. The munition is loaded as a complete cartridge. Single or multiple crimp rings are common and unique to this design.

Separated: Projectile comes separated from the cartridge case. The open end of the cartridge case is sealed and the propellant charge

cannot be accessed or altered. To load, the projectile is seated in the chamber and the cartridge containing the propellant is loaded behind it.

Semifixed: Projectile is set into the cartridge case for shipping, but it can be easily pulled out. To load, the projectile is removed from the

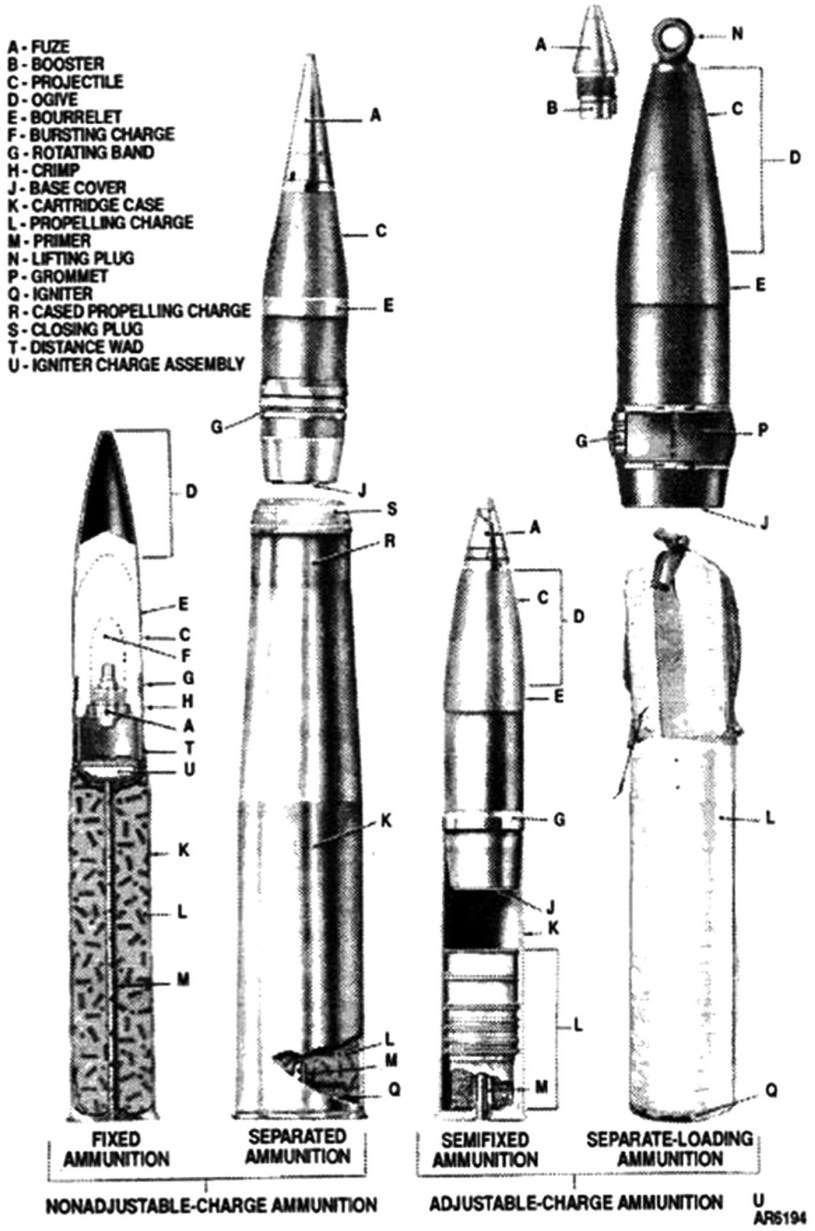

Figure 4.1 Projectile configurations. (From U.S. Military TM.)

cartridge, the propellant charge is adjusted, the projectile is placed back in the cartridge, and the complete munition is loaded.

Separate Loading: Projectile is separate from the propellant charge and there is no cartridge case. To load, the projectile is seated in the chamber and bags containing the propellant charges are loaded behind it, allowing the quantity of propellant to be adjusted while loading.

Key Identification Features

A projectile can be a teardrop, square, or dart-shaped munition with fins for stabilization, or a finless munition stabilized by spin generating centrifugal force. Early spherical cannonball-type projectiles were essentially thrown toward a target without a means of stabilization, resulting in poor range and accuracy. The development of elongated shaped projectiles fired through rifled bores capable of imparting spin to gyroscopically stabilize flight, greatly enhanced range, accuracy, and the velocity of projectiles. The shape and means of stabilization also provide identifying features that greatly assist in determining the projectile group and the associated safety precautions (Figure 4.2).

Worldwide there have been millions of different projectile designs developed since the early 1900s, ranging in size from 20mm to the behemoth 914mm (36 inch) American siege mortar "Little David."

Projectile Sections and Defining Features

Starting from the front or point of a projectile, the following definitions apply.

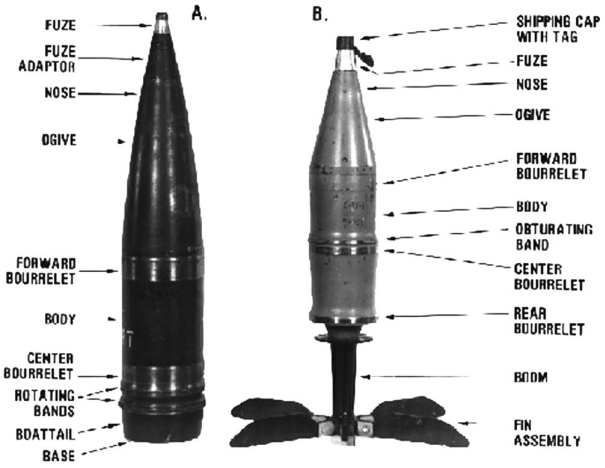

Figure 4.2 Basic configuration of Russian spin stabilized projectile (left) and a full or partially fin stabilized projectile (right). (From U.S. Military TM.)

Nose: The forward end of a projectile. May have a fuze-well, be solid, or be defined by the shape of the ogive.

Ogive: Is aft of the nose, and forward of the bourrelet. May house a fuze adapter with a shape consistent with the contour of the ogive. Ogives may be flat, rounded, conical, or spike-shaped with varying lengths, all of which greatly influence flight characteristics of a projectile.

Most nose-fuzed projectiles have a conical-shaped ogive. Flat ogives are common on canister type anti-personnel (APERS) projectiles designed to travel very short distances. Spikes, fracture rings, hammer rings, adapters, and other configurations provide insights on the group a munition belongs to (Figure 4.3).

Bourrelet: The section between the ogive and the body of a projectile. Some projectiles have a second bourrelet on the body, just forward of or below

Figure 4.3 Examples of projectile nose and ogive configurations. Left to right, top row: (1) Hammer or fracture rings are ID feature for an AP projectile. (2) Smooth-rounded ogive of light material is consistent with a HEP projectile. (3) Flat ogive of thin metal indicates a canister projectile. Left to right, bottom row: (1) Elongated ogive with no breaks is consistent with a HE projectile. (2) A standoff spike design is a key identification feature for HEAT projectiles. (3) An elongated ogive with an adapter can mean a few things; i.e., an adapter to accommodate a variety of fuzes for an HE munition, or it may be a burster-adapter used to seal in a White Phosphorus (WP) or chemical filler. (Author's photograph.)

the rotating band. The bourrelet is a slightly raised surface on the projectile designed to maintain slight contact with the inside of the bore to center the projectile as it travels down the barrel and to stop vibrations.

Diameter measurement is taken at the bourrelet as it is the true diameter of the projectile. If a bourrelet is not found, measure at the junction of the ogive and the body (Figures 4.1, 4.2 and 4.4).

Body: For projectiles, this is the cylindrical section between the forward bourrelet and the rotating band. Designs vary, but the body is usually a few millimeters smaller in diameter than the bourrelet. Being smaller than the bourrelet, the body does not contact the bore thus greatly reducing wear on the barrel (Figure 4.5).

One of the two most common places to find stamped markings is on the body. Different countries favor different locations, but common areas are just above the rotating band or mid-body (Figure 2.4).

Rotating Band, Gas-Check Band, or Obturator Ring: Depending on the delivery system, there are a few different band designs serving a similar purpose.

Rotating Band: Defined as a soft metal band near a projectile base designed to provide a tight fit in the bore to prevent gas from escaping, while also engaging the rifling to impart spin. But it also provides many identifying

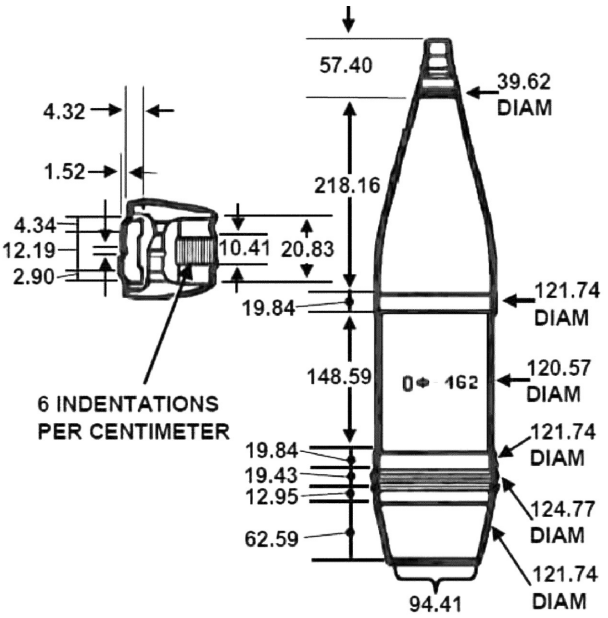

Figure 4.4 Measure the true diameter of a munition at the bourrelet. The forward and rear bourrelets are 121.74mm (4.79in) on this Russian 122mm (4.8in) projectile. The true diameter of the projectile will be smaller than the bore diameter to allow the munition to move through the barrel. (From U.S. Military TM.)

Figure 4.5 Measuring at the bourrelet. The yellow arrows point to the top and bottom of the forward bourrelet.

characteristics (Figure 4.6). Older designs used lead, nitrated paper, and other materials covered in Chapter 13.

Gas-Check Bands: Defined as a series of groves cut into a projectile body just below the bourrelet to keep gas behind the projectile until it has left the muzzle (Figure 4.7).

Obturator Ring: Defined as a device incorporated to make the tube of a gun gas-tight until the projectile has left the muzzle. A piece of expandable

Figure 4.6 Rotating Bands, from left to right, top row: (1) Unfired artillery projectile, note the smooth appearance. (2) Fired artillery projectile, note the scoring and distorted bottom edge of the band. (3) Rotating band with two cannelures on an unfired artillery projectile. From left to right, bottom row: (1) Prominent double rotating band configuration. (2) Pre-scored rotating band consistent with recoilless rifle projectiles, note the lack of distortion on the bottom edge and compare with top-row. (3) Pre-scored rotating band on a mortar. (Author's photograph.)

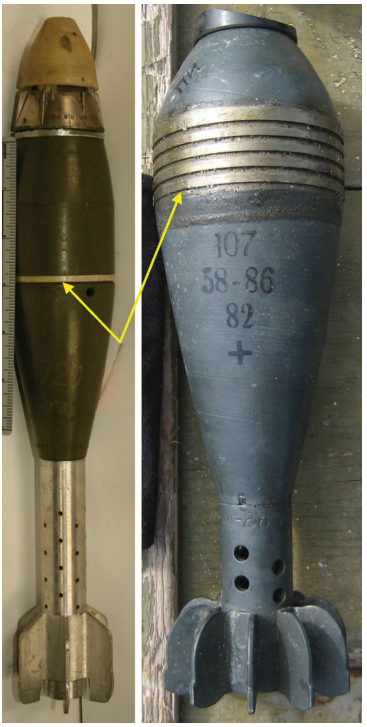

Figure 4.7 Obturator Rings and gas-check bands serve the same purpose, to trap gas behind the projectile when fired. On the left, the yellow arrow points to the white-plastic obturator ring on a U.S. 60mm mortar. On the right, gas-check bands are pointed out on this Russian 82mm mortar. (Author's photograph.)

plastic sits in a grove at the bourrelet and seals the gaps around the projectile, as seen in Figure 4.7.

Artillery projectiles usually have rotating bands made of copper, brass, sintered iron, or plastic. They may be narrow or wide, smooth, or have circumferential grooves called "cannelures" machined into them to catch shavings and reduce friction when fired. (Figure 4.6). After firing, the grooves cut by the barrel result in a wavy bottom edge as seen in Figure 4.6.

Recoilless rifle projectiles may have a single rotating bourrelet or a very wide bourrelet designed to act as a gas-check. Some rotating bands on recoilless rifle projectiles have a unique characteristic in that they are pre-scored in order to be fitted into the riflings of a bore. Note the difference between the lower edge of the rotating bands in Figure 4.6.

Gun projectiles are commonly fired from ships, tanks, and field pieces designed to fire at extremely high velocities. In order to increase velocity, these projectiles incorporate multiple, large, or overly prominent rotating bands as seen in Figure 4.6. Smooth-bore guns are often used to decrease friction and increase velocity, but projectiles from these guns require fins or cone for

stabilization and do not have rotating bands. Other designs incorporate a fin-spin, or cone-spin combination for stabilization; in this case, a thin rotating band and fins canted to impart additional spin are seen as in Figure 4.2.

Mortars are unique as early designs focused on delivering a projectile over a significant obstacle in a lobbing-type trajectory. However, mortars evolved into one of the most often used battlefield weapon systems involving every possible projectile configuration. The most common mortar design uses gas-check bands or an obturator ring versus a bourrelet, (Figure 4.7) thus resulting in most mortars having fins. There are also spin stabilized, finless mortars with rotating bands as seen in the bottom-right picture in Figure 4.6.

If a projectile is intact and the rotating band is missing, its "seat" or the groove in the body where it would have been will be observable. In this situation, the pattern of indentations in this groove will be very helpful in the identification process. If gas-check bands are present, the number, depth, and width will help during the identification process. After firing, an obturator ring pops off and will not be present; yet with few projectiles applying this design, it will be a helpful feature during the identification process.

Base: The bottom, rear, or end of a projectile that may or may not contain a fuze. There are a number of key identification features associated with the base of a projectile that can assist in the identification process, including stamped markings. Projectiles may have a square, boat-tailed, recessed, or curved base that can be welded, cast, pressed flush or countersunk as seen in Figure 4.8. The presence of crimping rings between the rotating band and base of the projectile may allow differentiation between similar projectiles. Crimp rings can be seen in two of the projectiles in Figure 4.6. Other features

Figure 4.8 Examples of 105mm (4.13in) artillery projectile base configurations. From left to right: British L31A3 HE, U.S. M314A3 illumination, U.S. M84 HC smoke, U.S. M444 submunition dispenser, U.S. M546 flechette with smoke-spotter, and U.S. M548 HERA/RAP. (Courtesy of Dan Evers.)

include fins, a tracer element, venturi, or nozzles that obscure the base and complicate determining if a base fuze is present (Figures 4.9 and 4.10).

Conversely, determining if a nozzle is a tracer, RAP, or base burner element can be difficult. Tracer elements vary in size and shape and may cover a base fuze. An example of a venturi or nozzle of a rocket-assisted projectile is provided in Figure 4.8.

Base burner or "fumer" elements also employ propellant, but in a very different way. Moving through the air, a projectile develops a vacuum just off the base that accounts for 50% of the overall drag associated with the

Figure 4.9 Examples of fin or fin-spin stabilized projectile base configurations. From left to right: Folding fins that deploy after leaving the barrel. Open fixed-fin design common on mortars. Closed pre-scored fin design common on recoilless rifle projectiles. (Author's photograph.)

Figure 4.10 On the left: Three 85mm (3.34in) APHE projectiles with tracer elements covering a base fuze. The deep groove below the bourrelet is a fracture ring, which is a key identification feature. On the right: The base fuze in a HEP projectile, which is also covered by a tracer element. (Author's photograph.)

projectile's flight trajectory. During flight, a base burner or fumer, bleeds hot gas that disrupts the vacuum and drag on the projectile, thus greatly increasing the range (Figure 4.11).

Most countries do not produce cheat-sheets to assist in ordnance identification, but technicians working in the field should. Below are a few examples where the base configurations can help identify the filler of U.S.-manufactured artillery projectiles:

- High Explosive (HE): Older designs have a welded base with a thin sheet metal disk; the new M795 design has a shallow dog-dish-like shape with no weld or breaks (Figure 4.8).
- Submunition Dispenser, ICM: A boat-tail base with shear pins and a break just forward of the base indicates M39 or M43A1 submunitions. A boat-tail base without shear pins, and a break just aft of the rotating band indicates M42 submunitions or FASCAM (family of scatterable munitions), which are categorized as dispensed landmines. The base plate itself is aluminum with a concave shaped bottom.
- Bursting Smoke (WP): Older designs have a completely solid base, like the bottom of a cup. The new M825 base ejecting design has a dog-dish-like shape with a break just aft of the rotating band (Figure 4.8).
- Illumination: For older 105mm and 155mm projectiles, a straight base (not boat-tailed) a break approximately three-quarter inch forward of the base with shear pins one-quarter to one-half inch above the break indicates an illumination candle with parachute. However, the 155mm, M485 series with a boat-tailed base is an exception to this rule (Figure 4.8).

  The base plate itself is steel with a flat/flush shaped bottom. Some designs incorporate stake pins that can be seen on the base plate, near the edge. Stake pins run through the base plate into the projectile body to stop the base plate from spinning or shifting when fired.
- HC, White Smoke: A boat-tailed base with no shear pins on the side and a break on the bottom of the base plate with two spanner holes. When removed, the side of the projectile looks exactly the same. The base plate, or plug, is steel with a flat/flush shaped bottom. When removed, the base plate looks like an oversized hockey puck with two thin threads near the side with spanner holes where it threads into the bottom of the projectile.

Fin Assemblies: Fins are not always present as projectiles can be fin or spin stabilized. When present, fins offer many identifiable features. For example, if a mortar is embedded in the ground and only the fins can be seen,

Figure 4.11 A 155mm (6.1in) South African M1A1 HE projectile, with a lifting ring in the fuze well. Note the brown band and break just below the rotating band indicating the presence of propellant; in this case, a base-burner or fumer element. The "flutes" on the body are also a unique identification feature for this projectile. (Author's photograph.)

determining the diameter of the projectile is possible by measuring the diameter of the fins, which are slightly smaller than the diameter of the bourrelet as they had to properly fit into the same tube (Figures 4.7 and 4.9).

Fuze: Many projectile fuzes require three actions to arm that coincide with the deployment characteristics. Projectile nose fuzes are usually observable, but impact with a hard surface may render identification difficult. If a nose fuze is sheared off flush with the fuze well from impact, the components required to function the fuze may still be present inside the projectile. If a nose or base fuze can be seen, wrench flats, spanner holes or slots, and the overall construction will provide relevant information to its identity. Additionally, the presence of a fuze adapter or booster adapter between the fuze and projectile may help identify both the fuze and the projectile.

However, there are internal and other difficult to see fuze configurations offering few clues to their existence. An example would be the Base-Detonating (BD) element of a Point-Initiating Base-Detonating (PIBD) fuze seen in Figure 3.8, Chapter 3, and a BD fuze covered by a tracer element

(Figure 4.10). The possibility of unobservable fuzing must be considered until definitively ruled out.

Seven-Step Practical Process Applied to Projectiles

Examples of different designs, features, color codes, markings, and construction features are provided throughout this chapter.

Step 1: Gather Information, Approach, and Initial Inspection:

Attempt to identify from a safe distance with binoculars. Approach at a 45° angle from the rear, avoiding venturis and fuze sensing elements.

With sketch pad and camera, document identifying features including fins, rotating bands, venturis, leaking material, color codes, stamped markings, construction features, damage, signs of tampering or modification. Also note the location and width of the rotating bands, gas-check bands, obturator ring, crimping rings. Measure the width and length of each component as shown in Figure 4.5.

The three fastest means of researching an unknown projectile:

1. The diameter measured at the bourrelet
2. The overall length
3. The method of stabilization, i.e., fin, spin, or fin-spin

Step 2: Determine Fuze Group, Type, and Condition: If a projectile has been deployed (step 5), the fuze is considered armed. If the fuze is damaged, pins have been removed, or alterations have been made, it is considered armed. If visible, measurements for the fuze are taken separately from the munition.

Step 3: Determine Ordnance Category:

The category "projectile" is covered throughout this chapter.

Step 4: Determine Ordnance Group:

The identifiable characteristics associated with each projectile group are covered throughout this chapter.

Step 5: Determine if Munition was Deployed:

Inspect the projectile for impact-related damage; soot on the base or tail boom from propellant charge; missing pins or clips; and, if present, note if the rotating band is scored from firing.

Step 6: Determine Safety Precautions:

The safety precautions for each projectile group are covered in this chapter. Once identified, these precautions must be adhered too.

Step 7: Research Literature and Identify the Munition:

Apply the totality of measurements, color codes, stamped markings, and construction features to determine the group, and positively identify the munition and fuzing configuration.

Groups

In order to provide a congruent flow, the projectile category is divided into the following primary and supplemental groups:

1. High Explosive (HE)
   a. HE/Fragmentation (Frag)
   b. High-Explosive Incendiary (HEI)
   c. High-Explosive Plastic (HEP)
   d. Thermobaric
   e. HE-RAP
2. High-Explosive Anti-Tank (HEAT)
3. Guided projectiles, HE and HEAT
4. Armor Piercing (AP)
   a. AP
   b. APHE
5. Anti-personnel (APERS)
   a. Canister
   b. Shrapnel
   c. Flechette
6. Dispenser and Improved Conventional Munition (ICM)
7. Smoke
   a. Bursting smoke
   b. Burning smoke and Riot control
8. Illumination
9. Practice
10. Drill

Groups

1. Category: Projectile. Group: HE: Designed to explode and destroy targets with blast, fragmentation, and thermal effects. Explosive fillers in these projectiles range from less than an ounce to hundreds of pounds, in solid, pliable, or liquid form.

1.a. Category: Projectile. Group: HE/Frag: The most straightforward design of an explosive munition, consisting of a projectile body, single or dual fuzing, and high-explosive filler.

General identification features include (Figure 4.12):

Materials and Appearance:

- Heavy duty, one-piece construction.
- The United States does not commonly use fuze adapters with HE projectiles, but other countries do. When present, top-down slots

or side spanner holes on a fuze adapter may indicate a HE or WP filler.

- Welded base on older U.S. projectiles is positive identification for HE. However, many countries use solid base designs (Figure 4.8).
- Fin assemblies for recoilless rifle projectiles have ignition holes in the tail boom assembly. Fin assemblies for mortars have ignition holes in the tail boom assembly or between the fins (Figures 4.7 and 4.9).
- If ignition holes are present in the tail boom or fins, a primer and ignition assembly should be expected in the base of the tail boom.
- If a tail boom or fins are present, there will not be a venturi consistent with a rocket, or an open tube consistent with a rifle grenade, at the base.

Figure 4.12 The first two are 20mm HEI, the next three are 20mm HE projectiles, the projectile on the far right is a 23mm HEI. All have different internal configurations to meet different technical or tactical designs. (Author's photograph.)

- Naval projectiles tend to have a heavier body construction and extremely wide or multiple rotating bands to withstand the higher firing velocities.
- Most HE mortars have a teardrop shape. Exceptions include the U.S. 4.2in. (107mm) and 120mm mortars (4.72in).

Markings: Green or black body with yellow markings or a gray body with black markings are common. A brown band may be present to designate a base burner or rocket motor (Figures 4.7 through 4.12). Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: PD, BD, VT, MT, and ET fuzing.

General Safety Precautions:
- HE, frag, movement.
- Safety precautions for fuze, if present.

1.b. Category: Projectile. Group: High-Explosive Incendiary (HEI): An HE main charge enhanced with incendiary materials such as, aluminum, magnesium, or zirconium. These materials can be blended with the explosives prior to filling, added as incendiary pellets, or incorporated as a pyrophoric liner on the body.

General identification features include:

Materials and Appearance:
Construction and identification features consistent with HE projectiles.

Markings: Green or yellow body with yellow and red markings are common. Other colors such as an all-black body (Figure 4.12), stamped or stenciled markings, and symbols may also be present.

Red usually designates an incendiary projectile, but some countries use red to identify HE or HEAT munitions, and other countries add incendiary materials without an identifying color.

Common Fuze Configurations: PD, BD, and VT fuzing.

General Safety Precautions:
- HE, frag, movement, fire.
- Safety precautions for fuze, if present.

1.c. Category: Projectile. Group: High-Explosive Plastic (HEP): Contains a HE main charge configured to produce a specific effect. Also known as a "squashhead," a HEP projectile has a thin metal ogive and body filled with a pliable explosive and a solid base housing a BD fuze (Figure 4.13).

Figure 4.13 Cutaway of a 106mm U.S. M346A HEP Projectile. (Author's photograph.)

Upon impact with an armored target, the forward end of the projectile is "squashed" in a manner consistent with a wet paper towel hitting a wall. The BD fuze functions, detonating the main charge and producing a spalling effect on the inside of the armored vehicle. Against modern armor, HEP projectiles are ineffective and an obsolete design.

General identification features include (Figure 4.13):

Materials and Appearance:

- Short, dome-shaped ogive made of thin metal.
- Single-piece body construction.
- Heavy-duty base construction.

Markings: Green body with yellow or black markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: BD fuzing.

General Safety Precautions:

- HE, frag, movement.
- There are HEP projectiles converted to WP fillers.
- Safety precautions for fuze, if present.

1.d. Category: Projectile. Group: Thermobaric: Often mistakenly classified as "incendiary," these projectiles are designed to explode and produce extremely high blast pressures in enclosed space. Employing main charges that can be dispersed prior to functioning as designed, thermobaric projectiles are not common. An example is the Russian RPO disposable launcher being defined as an "infantry rocket flame weapon." However, the motor used to fire the RPO falls away and would not be present down-range, thus classifying an RPO as a projectile versus rocket.

General identification features include:

Materials and Appearance:

- Thin-skinned aluminum warhead.
- Color codes inconsistent with common schemes.
- Fin assembly on the aft end of the motor.
- One or more venturis on the base of the motor.

Markings: Color codes used for thermobaric projectiles are a departure from most standards. Using the RPO system as an example, the only way to know which warhead is present in a launcher is by the unique marking on the front cover plate. The RPO-A thermobaric warhead has two red stripes (Figure 4.14). The RPO-D smoke has one yellow stripe and contains red phosphorus. The RPO-Z incendiary

Figure 4.14 Russian RPO-A thermobaric projectile with disposable launcher and the special markings designating an RPO-A warhead. (Author's photograph.)

warhead has one red stripe and contains "pyrogel" a material that burns between 800°C to 1,000°C.

Common Fuze Configurations: BD fuze.

General Safety Precautions:

- HE, frag, fire, chemical, movement.
- Filler presents a significant Fire and Chemical threat.
- Ejection, EMR, static for an unfired motor.
- Safety precautions for fuze, if present.

1.e. Category: Projectile. Group: Rocket Assisted (RAP): Contains a rocket motor in the base, initiated when the projectile is fired to increase range (Figures 4.8 and 4.15). When used with a high-explosive projectile, the naming designation is High-Explosive Rocket Assist (HERA). With seven pounds of solid rocket propellant, as in the M549 in Figure 4.15, the ejection hazard is significant.

General identification features include:

Materials and Appearance:

- Heavy-duty, multi-piece construction.
- Nose fuze only.
- One or two breaks in the bottom half of the body.
- Venturi on the base.

Markings: Green body with yellow markings are common. There may be brown markings below the rotating band for the motor. Other colors, stamped or stenciled markings and symbols may also be present.

Common Fuze Configurations: PD, VT fuzing.

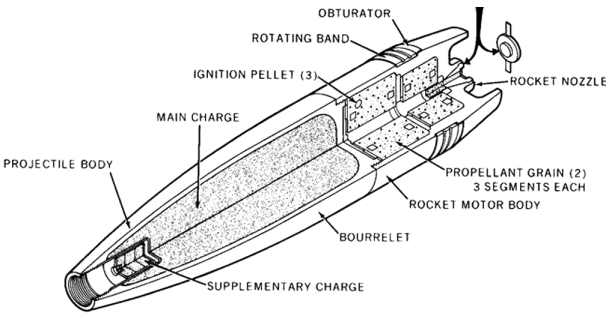

Figure 4.15 Line drawing of an M549, 155mm HERA/RAP configuration. (From U.S. Military TM.)

General Safety Precautions:

- HE, frag, movement, and ejection.
- Safety precautions for fuze, if present.

2. Category: Projectile. Group: HE-Anti-Tank (HEAT):

Contain a shaped charge to defeat armored and other hardened targets. In order for the shaped charge to form and maximize penetration, a standoff spike or hollow ogive is required. The hollow cone and ogive are reflected in the much lower explosive weights than HE munitions of similar size.

Most HEAT projectiles are between 30mm and 155mm in diameter. The majority of HEAT projectiles are fin stabilized to reduce the effects of centrifugal force on the shaped charge jet formation. There are many spin-stabilized HEAT projectiles that do not have centrifugal force-related issues. For those that do, a "fluted" cone offers an engineering solution as seen in Figure 3.8, Chapter 3.

General identification features include:

Materials and Appearance:

- Heavy duty, multi-piece construction.
- Break in the major diameter forward of the bourrelet.
- Standoff spike (Figures 4.3 and 4.16).
- Hollow ogive, crimped or screwed to the body.
- May have spanner holes where components meet.
- May have a tracer element on the base.

Markings: Green, black, or gray body with yellow or black markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: BD, PIBD electric and mechanical fuzing (Figures 3.8, 3.9, and 4.16).

General Safety Precautions:

- HE, frag, movement, jet.
- Many PIBD fuzing systems incorporate PE. Apply PE, EMR, static; until PE is conclusively ruled out.
- Safety precautions for fuze, if present.

3. Category: Projectile. Group: Guided: These are guidance system technologies used with HE and HEAT projectiles. Older technological designs include the U.S. Copperhead (Figure 4.17), incorporating infra-red (IR) guidance. Newer designs like the U.S. Excalibur, HE projectile use satellite-guidance.

Figure 4.16 Russian HEAT projectiles with standoff spikes and piezoelectric crystal PIBD fuzing. Left: 125mm 3BK-29 projectile. Right: 122mm BK-13 projectile. (Author's photograph.)

Figure 4.17 155mm, M712 U.S. Copperhead Guided Projectile. (Author's photograph.)

Often confused for missiles, guided projectiles do not have a motor and are constructed with a heavy body design to withstand the forces associated with firing a projectile at extreme range. For example, in Afghanistan, an Excalibur projectile successfully hit a point target at 36km. Guided projectile designs most often fall into the HE or HEAT groups.

General identification features include:

Materials and Appearance:

- Heavy-duty construction.
- High-quality machining of body, fins, screw heads.

- The presence of steerable fins consistent with missiles, but lacking motors or means of attaching a motor.

Markings: Green, black, or gray body with yellow or black markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: PD, BD, PIBD, or VT fuzing, which may not be externally visible.

General Safety Precautions:

- HE, frag, movement.
- HEAT if applicable.
- Ejection if fins are forcibly deployed.
- Chemical for damaged guidance systems containing heavy metals and other toxic materials.
- Safety precautions for fuze, if present.

4. Category: Projectile. Group: Armor Piercing (AP): The first munition specifically designed to defeat armored protection. Initial designs were nothing more than a hardened metal projectile that penetrated or spalled armor through kinetic impact. A Civil War projectile made to penetrate ironclad warships is covered in Chapter 13. Later designs included explosive charges behind a hardened nose to enhance penetration. Both designs have evolved over time and are still used today.

4.a. Category: Projectile. Group: AP: Does not contain explosives and is designed to spall or penetrate armor with kinetic impact. New armor configurations rendered the original AP projectiles ineffective (Figure 4.18), leading to new designs such as the armor-piercing fin-stabilized discarding sabot (APFSDS). An APFSDS is a dart-shaped body with a tear-shaped tungsten

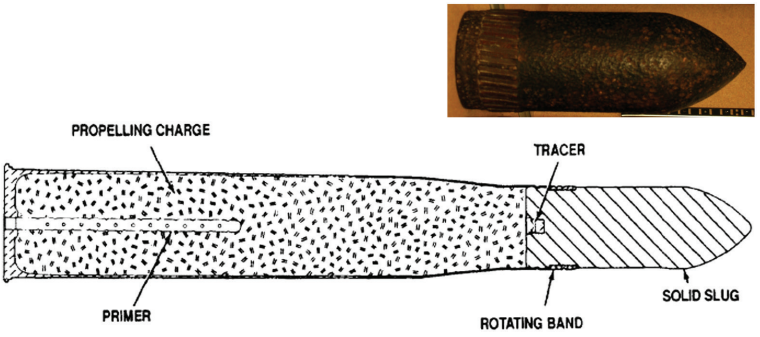

Figure 4.18 Line drawing of a 90mm Armor Piercing-Tracer (AP-T) from U.S. Military TM and a 90mm AP-T projectile. (Author's photograph.)

or depleted uranium (DU) core penetrator housed within the sabot (Figures 4.19 and 4.20). When fired, the penetrator and sabot travel down the bore. Upon exiting, the sabot parts separate from the subcaliber penetrator that is now propelled by the energy used to fire the full diameter and weight projectile. The result is a kinetic penetrator moving at speeds capable of effectively defeating the newest armor configurations.

General identification features include:

Materials and Appearance, AP Projectiles:

- Heavy body construction that comes to a dull point.
- May have a thin metal ballistic windshield over the nose to decrease resistance and increase velocity.
- May or may not have fracture rings.
- Multiple or a very wide rotating band (Figure 4.19).
- Tracer element on base.

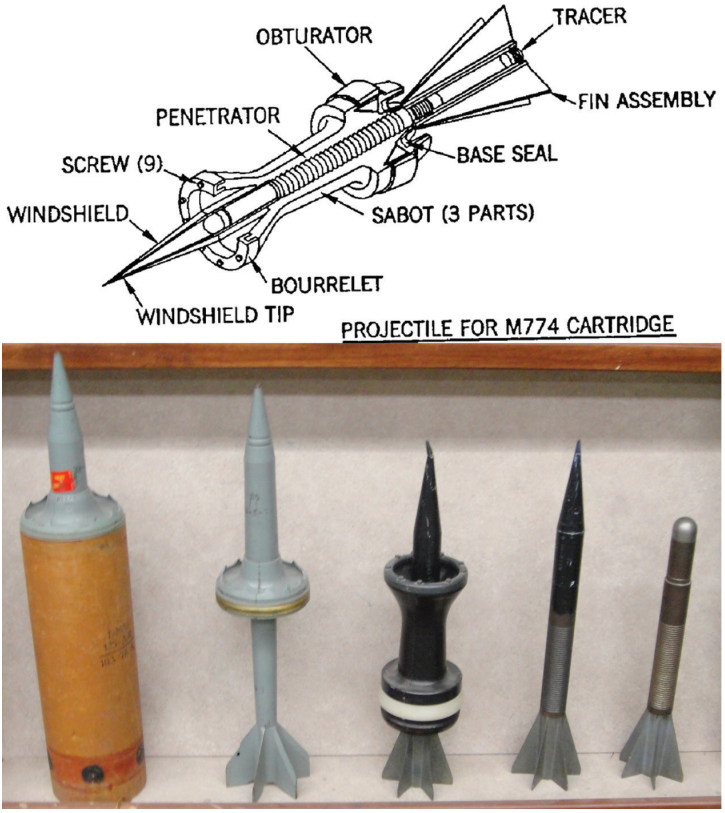

Figure 4.19 Line drawing of an APDS (From U.S. Military TM) and a variety of Russian and American APDS projectiles. (Author's photograph.)

Figure 4.20 U.S. 25mm APFSDS displayed in front of 3in (76.2mm) of rolled-homogeneous armor (RHA) hit with the same projectile. (Author's photograph.)

Materials and Appearance, APDS Projectiles:

- Solid, one-piece body that comes to a dull point.
- Ribbed rings on mid-body (Figures 4.19 and 4.20).
- Fins larger in diameter than the penetrator.
- Tracer element on base.

Markings: Black or gray body with white or black markings are common. If a tracer element is present, a "T" designation may be present on the projectile. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: None.

General Safety Precautions:

- Movement.

4.b. Category: Projectile. Group: Armor Piercing-High Explosive (APHE): Designed to spall or penetrate armor with kinetic impact. An APHE projectile employs fracture rings, a ballistic cap secured with hammer rings on the body, and an explosive charge in the base to intensify energy transmission (Figure 4.10).

General identification features include:

Materials and Appearance:

- Solid body that comes to a dull point.
- Fracture rings (Figures 4.3 and 4.10).
- Hammer rings securing a ballistic cap.
- A threaded or pressed on ballistic windshield.
- Multiple or a wide rotating band.
- Tracer element on base.

Markings: Green, black, or gray body with yellow, white, or black markings are common. If a tracer element is present, a "T" designation may be present on the projectile. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: BD.

General Safety Precautions:

- HE, frag, movement.
- Safety precautions for fuze, if present.

5. Category: Projectile. Group: Anti-Personnel (APERS): Specifically designed to propel large amounts of shot, shrapnel, or flechettes against personnel in the open. There are three basic configurations used to address different ranges, two of which have remained fundamentally unchanged for hundreds of years:

5.a. Category: Projectile. Group: APERS, Canister: A projectile design that converts a field gun into an oversized shotgun. Upon firing, the outer casing immediately strips away when exiting the bore, dispersing the canister shot (Figure 4.21).

General identification features include:

Materials and Appearance:

- Flat nose with no observable fuzing.
- No ogive.
- May have a tracer element.
- Aluminum or sheet metal construction with longitudinal scores on the body for easy opening.

Markings: May be painted black, green, or gray.

Common Fuze Configurations: None.

General Safety Precautions:

- Movement, ejection.

5.b. Category: Projectile. Group: APERS, Shrapnel: The classic "shrapnel" design employs a PTTF that functions after a predetermined time. A flame from the fuze travels down an internal tube to a black powder expelling charge in the base of the projectile. The base is strongly constructed so when the black powder explodes, the force propels the payload of shrapnel, fuze, and fuze adapter in a forward direction (Figure 4.22).

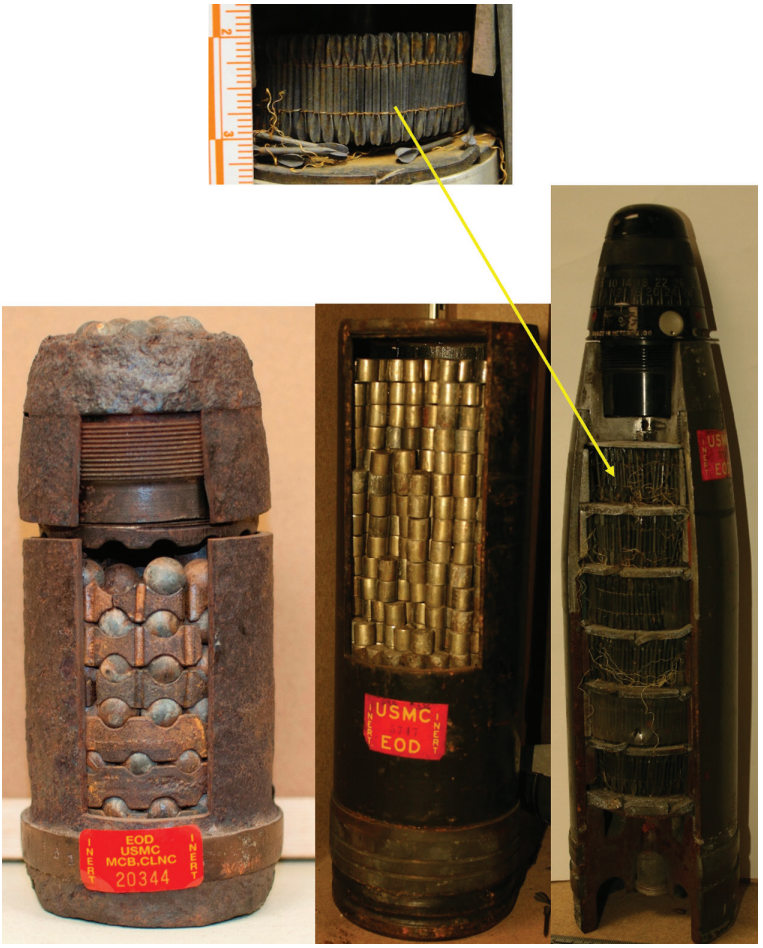

Figure 4.21 APERS projectiles, left to right: U.S. post-Civil War Hotchkiss, U.S. 90mm M336 canister with barrel-shaped shot, U.S. 90mm M580 flechette with a special MT fuze set to meters for short-range air-burst. (Courtesy of Dan Evers.)

General identification features include:

Materials and Appearance:

- Steel construction with a solid body.
- Fuze adapter.
- May have a tracer element.

Markings: May be painted black, green, or gray.

Common Fuze Configurations: PTTF.

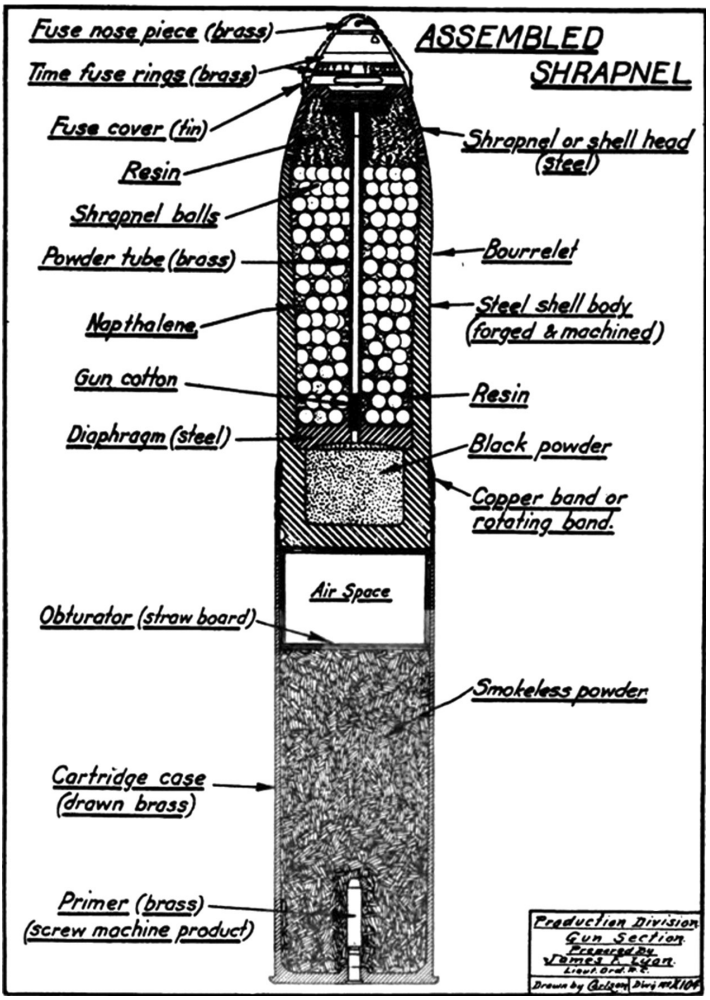

Figure 4.22 75mm shrapnel projectile. (From U.S. Military TM.)

General Safety Precautions:

- Movement.
- Ejection for shrapnel and fuze, as well as the body.
- Safety precautions for fuze, if present.

5.c. Category: Projectile. Group: APERS, Flechette: A more modern configuration incorporating a specially designed MT fuze set to meters versus time to ensure a short-range airburst. The high-explosive burster charge disperses flechettes at a 90° angle to the direction of flight, while momentum carries the flechettes forward at high velocity (Figure 4.21).

General identification features include:

Materials and Appearance:
- Conventional projectile shape.
- Aluminum or sheet metal construction with longitudinal scores on the body for easy opening.
- May have a tracer element.

Markings: May be green or gray with yellow or black markings, and a row of white diamonds on the body.

Common Fuze Configurations: PTTF, MT fuzing.

General Safety Precautions:
- HE, Movement.
- Ejection for side-body panels and flechettes.
- Safety precautions for fuze, if present.

6. Category: Projectile. Group: Dispenser and Improved Conventional Munition (ICM): The term "improved conventional munitions" is reserved for dispensers containing HE or HEAT submunitions. After firing, a time fuze functions at a predetermined time to initiate a low-explosive expelling charge. The pressure generated in the hollow ogive overcomes the pressed or threaded baseplate or nose ejecting the payload (Figures 4.23 and 4.24).

After an ICM has functioned as designed and the payload has ejected, all that should remain is the empty projectile body with a functioned fuze. After separating from the projectile, the payload is categorized under submunition. Other dispenser-type projectiles, such as bursting smoke, burning smoke, and illumination are covered later in this chapter. However, ICMs differ from these as they can dispense a payload, or with the addition of a booster, function upon impact as an enhanced fragmentation projectile.

Most dispensers eject from the base, but there are forward ejecting configurations. Forward ejecting models tend to have a semi-flat nose that is crimped or pressed in place, and a base fuze. (Figures 4.23 and 4.24).

General identification features include:

Materials and Appearance:
- Multi-piece body of steel and aluminum.
- Some designs incorporate a fiberglass wrap around the body that is externally visible.
- Rotating band, gas-check bands, or an obturator ring.
- Separate base plate that may have shear pins above the base.

- When fins are present, shear pins may be where the tail boom attaches to the body.
- A crimped or pressed nose cap may not have shear pins.
- A countersunk base with spanner holes or slots.

Figure 4.23 U.S. 155mm M483 ICM, containing a payload of 88, M42 and M46 submunitions. (Author's photograph.)

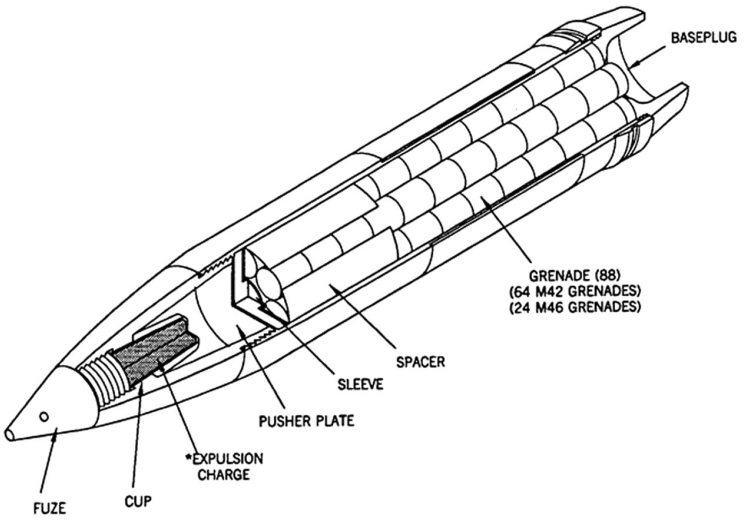

Figure 4.24 U.S. 155mm M483 ICM. (From U.S. Military TM.)

Markings: The payload will define the color codes and markings. Stamped or stenciled markings and symbols may also be present.

Common Fuze Configurations: MT, PTTF, and ET fuzing with an impact feature

General Safety Precautions:

- Movement, ejection.
- Explosively ejected payloads offer substantial hazard.
- Depending on the payload, HE, frag, jet may apply.
- Safety precautions for fuze, if present.

7. Category: Projectile. Group: Smoke: Designed to produce smoke for screening, marking; and fire for destroying targets. There are two distinctly different types of smoke projectiles; bursting smoke and burning smoke. Projectiles that deploy riot control agents are configured the same as burning smoke designs and are addressed under this group.

7a. Category: Projectile. Group: Bursting Smoke, White Phosphorus (WP): There are two types of bursting smoke projectiles that function in distinctly different manners:

Type 1: WP is sealed in the projectile with a burster adapter, containing a high-explosive burster extending from the fuze well, down the center of the projectile. Upon impact with the ground, the PD fuze detonates the burster, breaking the projectile body into a few large pieces while dispersing the WP filler (Figure 4.25).

Type 2: A newer design in which a projectile dispenser is loaded with a hermetically sealed steel canister containing felt wedges impregnated with WP. At a predetermined time during flight, the time fuze functions, initiating the low explosive expelling charge to eject the container and initiate a short delay. The delay detonates the burster running down the center of the container, breaking it apart and dispersing the WP soaked felt wedges (Figure 4.25).

General identification features include:

Materials and Appearance:

Type 1:

- Solid, one-piece body of robust construction.
- Burster adapter between the ogive and fuze, which seals the WP.
- The adapter booster may have wrench flats or spanner holes.
- On non-U.S. ordnance, top-down or side spanner holes on the adapter may indicate HE or WP.

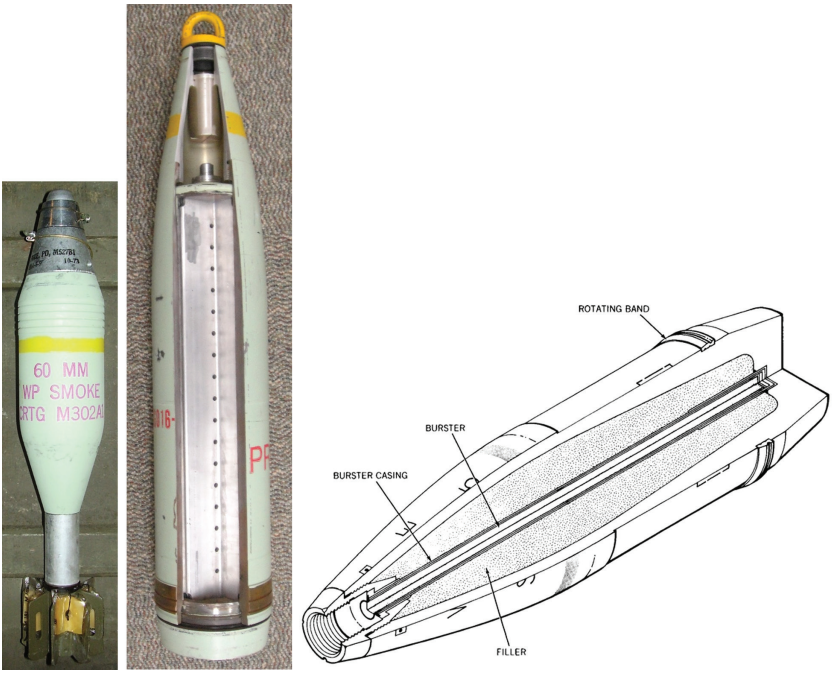

Figure 4.25 WP projectiles. The U.S. 60mm on the left is internally configured the same as the line drawing of the U.S. 155mm projectile on the right. The U.S. M825, 155mm in the center is base ejecting WP projectile. Note the pressure chamber in the ogive section and the pressed base plate (Author's photograph.)

- Rotating band, gas-check bands, or obturator ring.
- A flush solid base.

Type 2:

- A multi-piece, steel body and aluminum ogive.
- Rotating band just forward of the break where the base ejects (Figure 4.25).
- A countersunk base with spanner holes or slots.

Markings: Lime green or gray body with yellow and red markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations:

- Type 1: PD fuzing.
- Type 2: MT or ET fuzing.

General Safety Precautions:

- HE, frag, movement, WP, fire.
- Ejection, for base-ejecting model.
- Chemical if burning, WP smoke is toxic.
- Safety precautions for fuze, if present.

7b. Category: Projectile. Group: Burning Smoke (colored) and Riot Control: Consist of a dispenser-type projectile that ejects burning smoke canisters with pyrotechnic mixtures that burn to produce of colored smoke for signaling and screening. The only difference between colored smoke and riot control projectiles are the CN, CS, CN1, or other pepper-like riot control substances used in the later.

After firing, a time fuze functions at a predetermined time, initiating a low-explosive expelling charge; the pressure generated in the ogive overcomes the pressed or threaded baseplate or nose, ejecting the payload (Figures 4.8 and 4.26).

General identification features include:

Materials and Appearance:

- Multi-piece steel.
- Rotating band, gas-check bands, or obturator ring.
- A flush solid base.

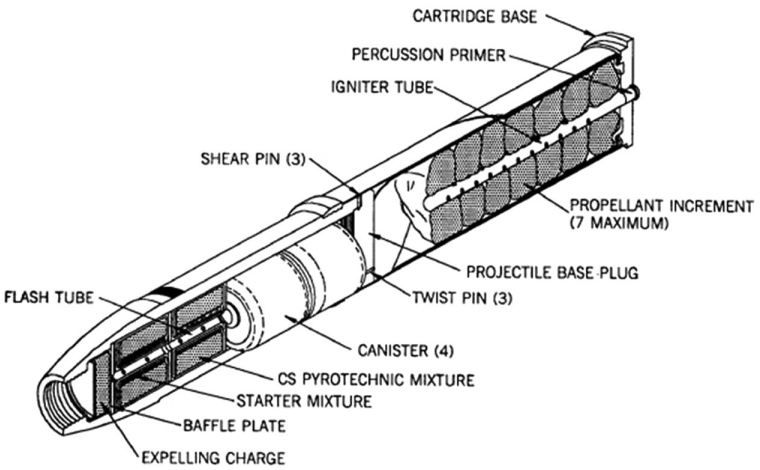

Figure 4.26 Line drawing of a 105mm, M629 CS Projectile. (From U.S. Military TM.)

Markings:

- A lime green or gray body with yellow and red markings are common.
- Riot control payloads usually have red markings designating the specific filler.
- Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: MT, PTTF, and ET fuzing.

General Safety Precautions:

- Movement, fire, ejection.
- Explosively ejected payload offers substantial hazard.
- Chemical for burning riot control.
- Chemical for burning, white HC smoke, which is toxic in field concentrations.
- Safety precautions for fuze, if present.

8. Category: Projectile. Group: Illumination: A dispenser-type projectile that ejects a parachute-suspended, pyrotechnic candle to illuminate an area at night. After firing, a time fuze functions at a predetermined time, initiating a low-explosive expelling charge, the pressure generated in the ogive overcomes the pressed or threaded baseplate or nose, ejecting the candle. The illumination candle may be ignited during ejection, or upon parachute deployment via a separate fuzing system. Depending on the projectile size, candles can range in intensity from a few thousand to millions of candlepower.

General identification features include:

Materials and Appearance:

- A multi-piece steel body and aluminum ogive.
- Rotating band just forward of the break where the base ejects.
- Most configurations are nose fuzed, base ejecting (Figures 4.27 and 4.28).
- Base-fuzed, front ejecting versions are less common, see Figure 4.28.

Markings:

- White, green, or gray body with black, red, and brown markings are common.
- The umbrella-like symbol, in Figure 4.28 is often used to identify illumination munitions for all ordnance categories.
- Other colors, stamped or stenciled markings, and symbols may also be present.

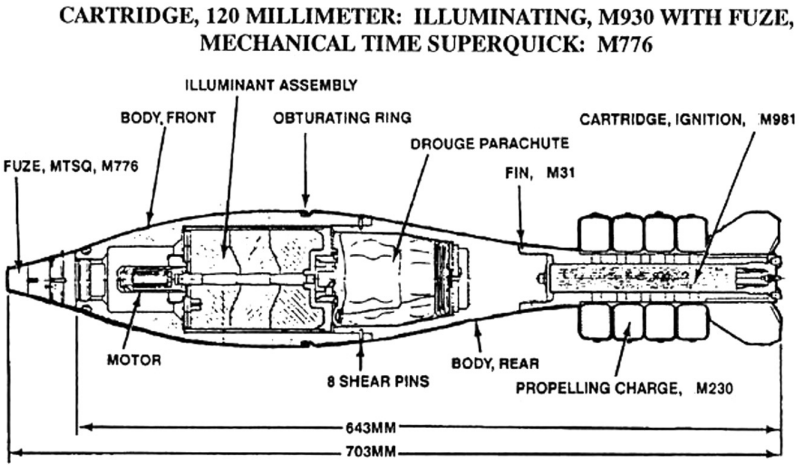

Figure 4.27 U.S. 120mm M930 illumination projectile. (From U.S. Military TM.)

Figure 4.28 Illumination mortars, left to right: U.S. 60mm fin stabilized mortar with a PTTF on nose. Belgian 60mm fin stabilized mortar with a base MT fuze. U.S. 120mm spin-stabilized mortar, note pre-scored rotating band and umbrella-like symbol to identify an illumination munition. (Author's photograph.)

Common Fuze Configurations: MT, PTTF, and ET fuzing to deploy the payload. Candle may be ignited by the ejection charge, or during parachute deployment via a mechanical pull-initiated fuze.

General Safety Precautions:

- Movement, fire, ejection.
- Explosively ejected payload offers substantial hazard.
- Chemical if burning as smoke is toxic.
- Do not look directly at a burning candle.
- Safety precautions for fuze, if present.

9. Category: Projectile. Group: Practice: Designed to fire with the same ballistic characteristics as the live projectile it mimics, minus the destructive effects. Some are full sized, while others are subcaliber projectiles fired through modified weapon systems. Practice projectiles may be solid metal, contain an inert filler such as gypsum and wax to simulate explosives weight, or powdered dye that bursts to leave a large mark when impacting a target. Other designs contain a live fuze with an explosive charge to propel chlorosulphonic acid (FS) or other spotting materials so the point of impact can be seen at great distance (Figure 4.29).

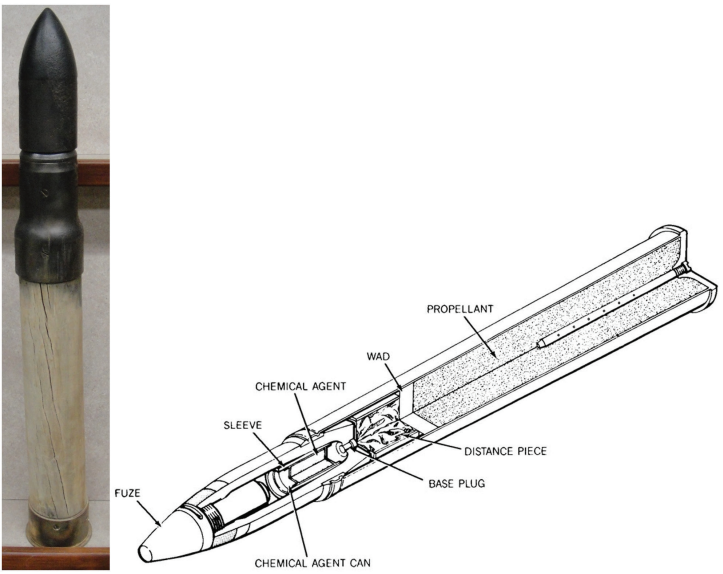

Figure 4.29 On the left is a U.S. Navy drill round with wooden body possessing no hazards. (Author's photograph.) Not to be confused with the U.S. 76mm, MK167 "Practice" projectile containing 4.1 ounce, explosively dispersed, liquid FS spotting charge. The component identified as "Chemical Agent" is FS, see Chapter 1. (From U.S. Military TM.)

General identification features include:

Materials and Appearance:
- Construction features consistent with the projectile they are designed to imitate.

Markings:
- Blue or black with white or brown markings are common.
- "TP" for target practice is found on many practice projectiles with no energetics or spotting charges.
- Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: If fuzed, the fuze will be the same type employed on the projectile being imitated.

General Safety Precautions:
- Movement.
- Observe all applicable safety precautions for the live projectile until positive identification is made.
- HE, frag, ejection when a spotting charge is present.
- Safety precautions for fuze, if present.
- Practice means practice, it does not mean inert.

10. Category: Projectile. Group: Drill: Unable to be fired, these projectiles are designed to be used for weapon system loading and unloading drills, or for display; they contain no energetic materials whatsoever (Figure 4.29).

General identification features include:

Materials and Appearance:
- Construction features generally consistent with the projectile they are designed to imitate.
- Older models were made with wooden components.

Markings: Gold or blue body with white markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: None.

General Safety Precautions:
Movement, until positive identification is made.

Closing

All ordnance, including practice projectiles are inherently dangerous. Until proven otherwise, always consider a projectile to be in a hazardous condition.

If unable to identify a projectile that appears to be over 100 years old, applying the information on older munitions from Chapter 13 may be helpful.

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Ordnance Category—Rockets

5

I certainly remember building model rockets. It was fun to watch the rocket blast into the air, suspenseful to wonder if the parachute would open to bring the rocket safely back.

Eric Allin Cornell, Nobel Prize in physics, 2001

Introduction

Of all the ordnance categories; rockets, as evidenced by Dr. Cornell's quote, seem to fascinate people more than any other ordnance category. Despite all the accomplishments this man has achieved, he still vividly recalled the enjoyment of a launch and the suspense associated with the intended parachute deployment from a child's hobby rocket. The fascination with a launch may also explain why modern-day fireworks shows are so popular.

The origins and developmental history of rocketry has been contested by historians over the last century, but may date back as far as 300 AD. Most Americans associate rockets with a line from "The Star-Spangled Banner," "…the rocket's red glare, the bombs bursting in air…," referring to the Congreve rockets fired at Fort McHenry from British ships in Baltimore Harbor during the War of 1812.

Early rocket designs used black powder as a propellant and main charge. Sir William Congreve successfully designed several different versions with a long wooden shaft to provide stabilization. The next leap in "rocket science" came from British inventor Sir William Hale, who successfully incorporated angled venturis to generate spin, resulting in stable flight and improved accuracy. But high rates of firing malfunctions and explosive accidents, generated a lack of trust in rocket technology limiting their use for over 200 years.

During WWI, American physicist Dr. Robert Goddard had great success using double-base powder for rocket propellent, leading to further developments in propellant formulas. These seemingly small changes allowed fielding of lightweight rockets that could be carried by infantrymen, and the tactical impact was great and immediate. The design characteristics seen in the German WWII Panzerschrek, and American "bazooka" are still seen on many shoulder-fired rocket systems today.

For this chapter, the defining factors categorizing a munition as a "Rocket" are:

1. The munition is propelled by a rocket motor as its primary means of deployment.
2. The munition is unguided and incapable of altering its trajectory while in flight.

These defining factors are easy to recognize if the motor remains attached to the warhead, which is not always the case.

There are exceptions to this definition, including terminology such as "RPG" (Rocket-Propelled Grenade) used to describe a reloadable infantry weapon. The term RPG represents an attempt at a literal translation that was incorrect, but generally accepted by the international community. Versions of these munitions can be categorized as rockets or projectiles, depending upon how they are propelled. It is important to know the difference when researching an unknown munition to enable accurate identification.

Rocket Types

There are two types of rockets, surface-to-surface and air-to-surface. Some designs can be fired from both ground and air platforms, but most are configured for one, making this a "Type" characteristic and helpful for identifying an unknown rocket. See Appendices D and E for information on marking schemes.

Surface-to-Surface Rockets: Are fired from the ground or water by infantrymen; or from vehicles, unmanned mounts, and ships (Figures 5.1 and 5.2). Vehicle mounted rocket systems can exceed 300mm (11.8in) diameter and 6.1 meter (20ft) in length.

Air-to-Surface Rockets: Are fired from aircraft, both fixed-wing aircraft, helicopters, and unmanned drones. Weight limits tend to keep these smaller, but there are models 240mm (9.45") in diameter.

Key Identification Features

If the rocket type can be ascertained, the number of possibilities will be cut by approximately 50%, which is very helpful during the identification process.

A rocket is a long, cylindrically shaped munition with a warhead and one or more motors containing one or more venturis and no evidence of steerable fins to allow the munition to change direction in flight. Rocket warheads share many shape consistencies with projectiles of similar groups and can

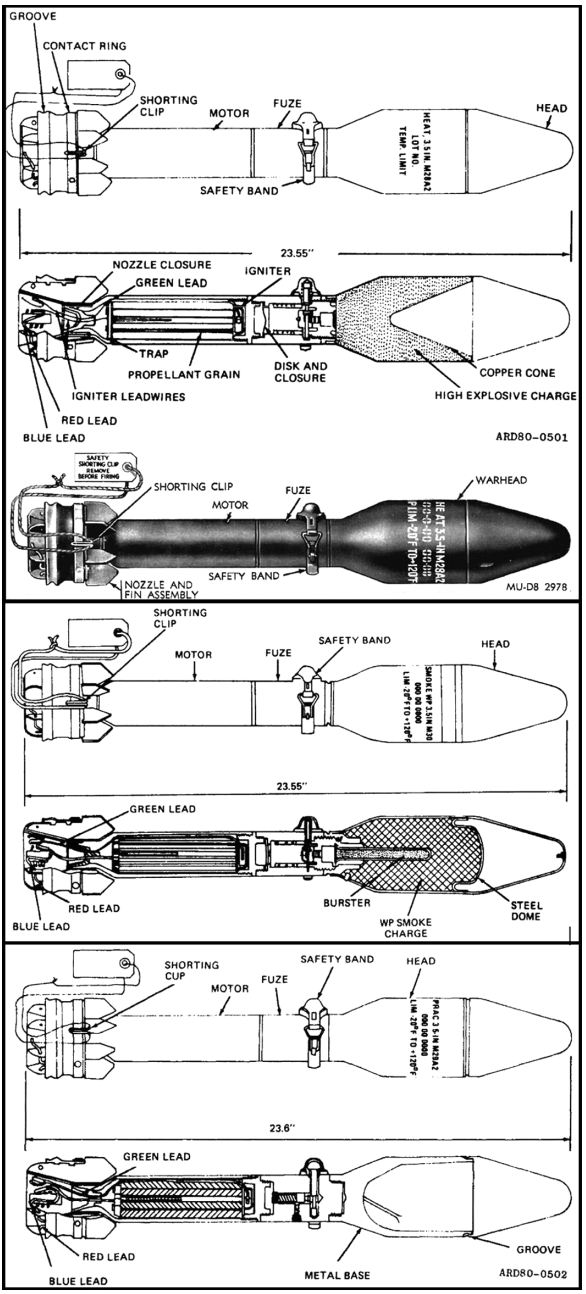

Figure 5.1 U.S. 3.5in (88.9mm) rockets and color codes, top to bottom: M28A2 HEAT, olive drab with yellow markings. M30 WP, gray with yellow markings. M29 practice, blue with white and possibly brown markings. Note the observable lead wires on the base of the motor (From U.S. Military TM.)

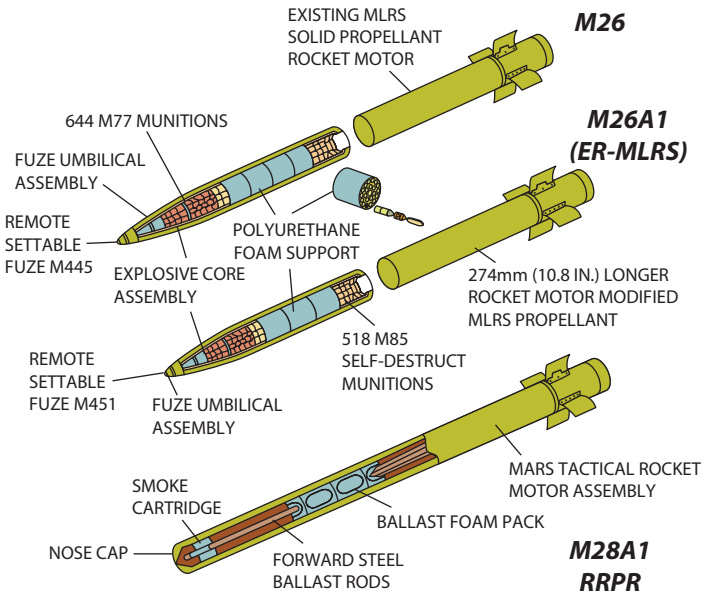

Figure 5.2 U.S. 227mm (8.94in) Multiple Launch Rocket System (MLRS), including the extended range (ER) motor and reduced range practice rocket (RRPR) configurations. (From U.S. Military TM.)

be easily mistaken for one if detached from the motor. When inspecting an unknown munition that could be a rocket, focus on these two areas:

1. The base of a rocket warhead will have a means of attaching a motor, such as threads or a grooved base to screw or clip on to the motor (Figure 5.3).
2. Rocket warheads do not have the rotating or gas-check bands consistent with projectiles.

Rocket Sections and Defining Features

Other than some practice rockets consisting of only a rocket motor, a rocket is a multi-piece ordnance item. At the very least, a warhead and motor section will be present. However, multiple motors, fin assemblies, cleats, rails, single or multiple venturis, and other components may also be present.

Starting from the nose or point of a rocket, the following definitions apply.

Warhead Section: Often referred to as the "body" in literature, the warhead defines the group to which a rocket belongs. Rocket warheads share many of the same characteristics as projectiles. The most important differentiating features are a base with a means of attaching to a motor, and the absence of rotating or gas-check bands (Figure 5.3). The nose, ogive,

Figure 5.3 U.S 2.75in (69.85mm) rocket warheads. The warhead on top clips onto the motor; the warhead on the bottom is screwed onto the motor. (Author's photograph.).

bourrelet, and base are all important sub-parts of the warhead and thus further defined.

Nose: The forward end of a warhead. May have a fuze-well, be solid, or be defined by the shape of the ogive.

Ogive: Is aft of the nose, and forward of the bourrelet. May house a fuze adapter with a shape consistent with the contour of the ogive. Ogives may be rounded or conical with varying lengths, all of which greatly influence a rocket's flight characteristics.

Bourrelet: The section between the ogive and body of a rocket. The bourrelet is a slightly raised surface on the rocket designed to maintain a light contact with the inside of the launching tube to center the rocket when fired.

Diameter measurement is taken at the bourrelet as it is the true diameter of the rocket. If a bourrelet is not found, measure at the junction of the ogive and the body as shown in Figure 5.4.

Base: The end of the warhead, which may or may not contain a fuze. The base of a rocket warhead will have a means of securing it to the rocket motor (Figures 5.1 and 5.3).

However, when a rocket warhead is found with the motor section missing, do not assume the base of the warhead is observable. Rocket motors may break off below the "cup" into or onto which the warhead is screwed or snapped, and this piece may be covering the actual base of the warhead. Careful inspection is required.

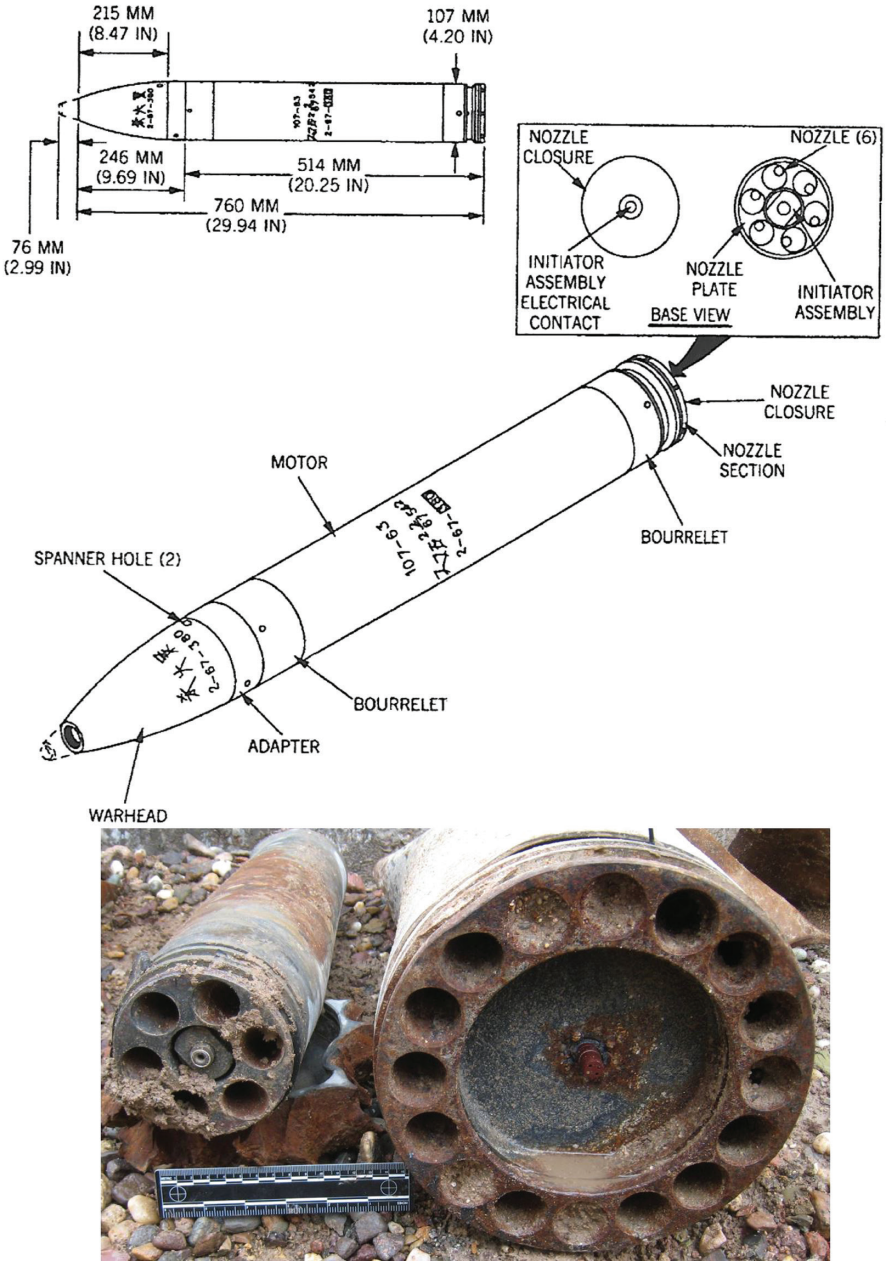

Figure 5.4 Top: A Chinese 107mm (4.21in) rocket (From U.S. Military TM). Bottom/left, a 107mm and right, a 240mm (9.45in) spin stabilized rockets. Note the venturis are angled to impart spin. (Author's photograph.)

Motor Section: Consists of a propellant filled motor, single or multiple venturis to control thrust, and fins for stability. All of which are important sub-parts of the motor section and thus further defined.

Motors: Rocket motors consist of a body, igniter, propellant, and one or more venturis. When fired, the igniter initiates the propellant, which generates pressure that escapes the motor through the venturi (Figures 5.1 and 5.4). Some rocket designs include a two-motor configuration with a launch motor and flight motor to increase range and stability. For example, the RPGs in Figures 5.5 and 5.6 are fired with propellant from a recoilless system, causing the fins to deploy and begin the fuze arming processes. Subsequently, the flight motor fires (Figure 5.6) to push the rocket on to its intended target. Due to the fact that a rocket motor is present after deployment, the RPG is classified as a rocket.

Venturi or Nozzle Assembly: The terms venturi and nozzle are often used interchangeably. For this text, the term venturi is used for continuity.

The diameter, pitch, slant angle, canting or fluting, and the number of venturis are used to control the release and direction of pressure generated by the propellant, and thus the thrust produced by the motor. Venturi design details can assist in identifying a rocket. Count the number of venturis, measure the inner diameter, and note the venturi type; i.e., straight, slanted, canted, fluted. (Figures 5.1, 5.4, and 5.6).

Figure 5.5 Top: RPG launcher and PG-7 rocket with the launch motor circled in yellow. Middle: The internal configuration of the launch motor with closed fins within the propellant. Bottom: Circled in yellow are the deployed fins after firing. (Author's photographs.)

Figure 5.6 RPG-7-type rockets from three different countries and the internal configuration of a RPG-9. The green caps on the base are removed to attach the propellant-fin assembly seen in Figure 5.5. The mid-body venturis circled in yellow are at the front of the flight motor on this design. The number and shape of the venturis are important identification characteristics as some countries use different configurations as shown in the example on the bottom-right. (Author's photographs.)

Fin Assembly: Fins are not always present as rockets can be fin or spin stabilized. When present, fins offer many identifiable features and may be mounted on the motor or another component of the rocket. They may be fixed and immovable (Figure 5.1) or open after deployment (Figure 5.5). Whatever the type, while in flight, fins help stabilize the rocket's trajectory. But these fins do not steer or offer a steering capability such as those found on a guided missile.

Fuze: Many rocket fuzes require three actions to arm that coincide with the deployment characteristics. Rocket nose fuzes are usually observable; however, impact with a hard surface may render identification difficult. If a nose fuze is sheared off flush with the fuze well from impact, the components required to function the fuze may still be present inside the warhead. If a nose or base fuze can be seen, wrench flats, spanner holes or slots, and the overall construction will provide relevant information to its identity. Additionally, the presence of a fuze adapter, or booster adapter between the fuze and warhead, or a bore-riding pin on the fuze may help identify both the fuze and the rocket.

However, there are internal and other difficult to see fuze configurations offering few clues to their existence. An example would be the Base-Detonating (BD) element of a Point-Initiating Base-Detonating (PIBD) fuze, and a BD fuze covered by the cup securing the motor to the warhead

(Figures 5.1 and 5.6). The possibility of unobservable fuzing must be considered until definitively ruled out.

The Seven-Step Practical Process Applied to Rockets

Examples of different designs, color codes, markings, and construction features are provided throughout this chapter.

Step 1: Gather Information, Approach, and Initial Inspection: Attempt to identify from a safe distance with binoculars. Approach at a 45°angle from the rear, avoiding venturis and fuze sensing elements.

With sketch pad and camera, document identifying features including fins, venturis, means of attaching the warhead to the motor, leaking material, color codes, stamped markings, construction features, damage, signs of tampering or modification.

Measurements must be taken of the warhead, and motor separately, as well as together for an overall length. The three fastest means of researching an unknown rocket are:

1. The diameter measured at the warhead bourrelet.
2. The overall length.
3. The method of stabilization; i.e., fin, spin, or fin-spin.

Step 2: Determine Fuze Group, Type, and Condition: If a rocket has been deployed (step 5), the fuze is considered armed. If the fuze is damaged or alterations have been made, it is considered armed. If visible, measurements for the fuze are taken separately from the munition.

Step 3: Determine Ordnance Category:

The category "rocket" is covered throughout this chapter.

Step 4: Determine Ordnance Group:

The identifiable characteristics associated with each rocket group are covered throughout this chapter.

Step 5: Determine if Munition was Deployed:

Inspect the rocket for impact-related damage, missing pins or clips. On the motor, look for blistered paint or heat-related markings indicating the motor has fired. Check venturis for closure disks or plugs; if missing, assume the rocket was fired.

Step 6: Determine Safety Precautions:

Safety precautions for each rocket group are covered in this chapter. Once identified, these precautions must be adhered to.

Step 7: Research Literature and Identify the Munition:

Apply the totality of measurements, color codes, stamped markings, and construction features to determine the group, and positively identify the munition and fuzing configuration.

Groups

The rocket category is divided into the following primary and supplemental groups:

1. High Explosive (HE)
   a. HE and HE-Fragmentation
   b. Bounding
   c. Thermobaric and Incendiary
2. HEAT
3. Dispenser
4. Bursting smoke
5. Illumination
6. Practice
7. Drill

Groups

1. Category: Rocket. Group: HE: Designed to explode and destroy targets with blast, fragmentation, and thermal effects. Explosive fillers in these rockets range from ounces to many pounds, in solid, pliable, or liquid form.

1.a. Category: Rocket. Group: HE and HE-Fragmentation: Is a general-purpose rocket configuration, consisting of a motor, warhead, single or dual fuzing, and high-explosive filler.

Included under the HE group are two designs providing greater effects, but both appear and function in the same manner as conventional HE rocket warheads. The two are:

1. HE-Frag: Consists of a warhead with multiple layers of enhanced fragmentation.
2. Semi-Armor-Piercing High-Explosive (SAPHE): An uncommon design displaying characteristics consistent with an HE warhead, with a base-fuze option only.

General identification features include (Figure 5.7):

Materials and Appearance:

- Warhead of heavy duty, one-piece construction.
- The United States does not commonly use fuze adapters with HE rockets, but other countries do. When present, top-down slots or side spanner holes on a fuze adapter may indicate a HE or WP warhead (Figure 5.11).

- Fin assembly on the aft end of the motor.
- One or more venturis on the base of the motor.
- Some designs have mid-body venturis (Figure 5.6).

Markings: Green or gray body with yellow or black markings are common on warheads. A brown band may be present on the motor. Warhead and motor colors may match or be completely different. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: PD, BD, VT fuzing. Depending on design, base fuzing may be covered by the motor and unobservable.

General Safety Precautions:

- HE, frag, movement for the warhead and motor.
- Ejection, EMR, static for an unfired motor.
- Safety precautions for fuze, if present.

Figure 5.7 Cutaway view of a basic HE/Frag rocket with a Point Detonating (PD) fuze. (Author's photograph.)

1.b. Category: Rocket. Group: HE Bounding: A configuration with few versions; the most common being the Chinese Type 69, which is used as an example for functioning purposes (Figure 5.8).

Upon firing, the Type 69 fuze will function upon impact with a target or upon a glancing impact when the "collar" between the fuze and the warhead digs in, lifting the base of the rocket upward while driving the fuze downward thus functioning it. Upon fuze functioning, an ejection charge explodes, ejecting the warhead while also igniting the pyrotechnic delay that initiates the warhead 3' to 4' (1 meter) from the point of impact.

General identification features include:

Materials and Appearance:

- Overall appearance is awkward and unbalanced.
- Multi-piece body, with breaks at the forward and rear ends of the warhead, but not at the major diameter. Often mistaken for a HEAT warhead due to the shape, as seen in Figure 5.1.
- An anti-ricochet collar between the fuze and the warhead.
- Fin assembly on aft end of motor.
- Mid-body venturis.

Markings: A green body with black markings are common. A brown band may be present on the motor. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: PD fuze for ejection charge, and short pyrotechnic delay for warhead.

General Safety Precautions:

- HE, frag, movement for the warhead and motor.
- Ejection, EMR, static for an unfired motor.
- Safety precautions for fuze, if present.

Figure 5.8 Chinese Type 69, bounding fragmentation rocket displayed with the shipping cap in place on the base and the unattached launch motor with fin assembly. (Author's photograph.)

1.c. Category: Rocket. Group: Thermobaric: Are designed to explode and produce extremely high blast pressures in enclosed space. Examples include the Bulgarian GTB-7VS and U.S. MK-80 SMAW-NE. The obsolete U.S. M74 "TEA" rocket seen in Figure 5.9 employs a volatile liquid main charge that also has an incendiary effect and is classified as such in some literature.

General identification features include:

Materials and Appearance:

- Thin or thick-skinned aluminum warhead.
- Fin assembly on the aft end of the motor.
- One or more venturis on the base of the motor.
- The M74 contains Tri-Ethyl Aluminum (TEA) housed in a thin aluminum body with a HE burster charge running down the center.

Markings: Color codes inconsistent with common schemes such as the anodized red body of the M74 (Figure 5.9). A brown band may be present on the motor. Other colors, stamped or stenciled markings, and symbols may be present.

Common Fuze Configurations: BD fuze.

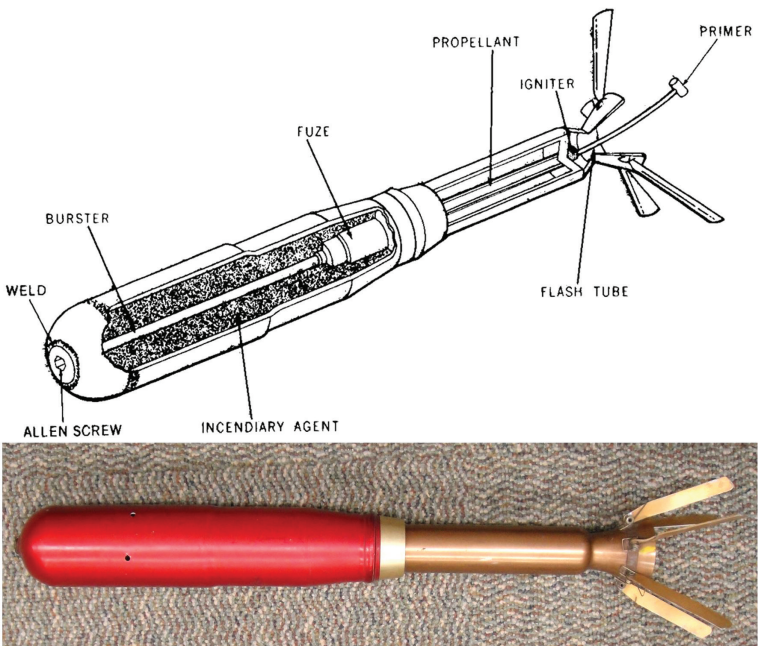

Figure 5.9 The internal configuration of the M74 TEA rocket (From U.S. Military TM) and the actual color scheme of the M74. (Author's photograph.)

General Safety Precautions:

- HE, frag, fire, chemical, movement for warhead and motor.
- Ejection, EMR, static for unfired motor.
- Filler presents a significant chemical threat.
- Safety precautions for fuze, if present.

2. Category: Rocket. Group: HEAT: Contain a shaped charge warhead to defeat armored and other hardened targets. In order for the shaped charge to form and maximize penetration, a standoff spike or hollow ogive is required. The hollow cone and ogive are reflected in the much lower explosive weights than HE rockets of similar size.

HEAT rockets designed for infantry are usually made of lightweight sheet-metal or aluminum (Figures 5.5 and 5.6); however, older versions were made of heavyweight metals (Figure 5.1). While those designed for aircraft incorporate lightweight materials, they often include anti-personnel fragmentation liners to increase peripheral lethality as seen in Figure 5.10.

General identification features include:

Materials and Appearance:

- Lightweight materials on newer models, steel on older models.
- Break in the major diameter forward of the bourrelet.
- Hollow ogive, crimped or screwed to the body.
- May have spanner holes used to tighten ogive.
- One or more venturis on the base of the motor.

Markings: Green, black, or gray body with yellow or black markings are common. A brown band may be present on the motor. Other colors, stamped or stenciled markings, and symbols may be present.

Common Fuze Configurations: BD, PIBD electric and mechanical fuzing.

Figure 5.10 Russian S5KO air-to-surface HEAT rocket with external coil-spring fragmentation sleeve. (Author's photograph.)

General Safety Precautions:

- HE, frag, movement, jet for warhead and motor.
- Ejection, EMR, static for unfired motor.
- Many PIBD fuzing systems incorporate PE. Apply PE, EMR, static; until PE is conclusively ruled out.
- Safety precautions for fuze, if present.

3. Category: Rocket. Group: Dispenser: A hollow warhead with a payload sealed inside. The term "dispenser" is reserved for warheads containing HE or HEAT submunitions.

After firing, a time fuze functions at a predetermined time to release springs or initiate a low-explosive expelling charge. The pressure generated in the hollow base or ogive overcomes the pressed or threaded baseplate or nose, ejecting the payload from the warhead (Figure 5.2). With the rocket motor fixed to the base of the warhead, most rocket dispensers are configured for a forward deployment.

After a dispenser rocket has functioned as designed, all that should remain is an empty rocket motor and an empty warhead body. After separating from the rocket, the payload is categorized under submunition. Other dispenser-type rockets, such as bursting smoke, burning smoke, and illumination warheads are covered later in this chapter.

General identification features include:

Materials and Appearance:

- Multi-piece, thin-skinned steel, aluminum, or fiberglass.
- Threaded or pressed nose cone that may be plastic.
- Spanner holes or shear pins that may be present on the nose cone or near the warhead–motor junction.
- Fin assembly on the aft end of the motor.
- One or more venturis on the base of the motor.

Markings: The payload will define the color codes and markings. A brown band may be present on the motor. Stamped or stenciled markings and symbols may be present.

Common Fuze Configurations: MT, ET, and PTTF fuzing.

General Safety Precautions:

- Movement, ejection for the warhead.
- HE, frag, EMR, static, ejection for unfired motor.
- Depending on the payload, HE, frag, jet.
- Explosively deployed payload offers substantial ejection hazard.
- Safety precautions for fuze, if present.

4. Category: Rocket. Group: Bursting Smoke, WP: Are designed to produce smoke for screening, marking; and fire for destroying targets. White phosphorus is sealed in the warhead by a burster adapter either on the base (Figure 5.1) or on the nose (Figure 5.11).

General identification features include:

Materials and Appearance:

- Solid, one-piece warhead body of robust construction.
- Burster adapter between the ogive and fuze, which seals the WP.
- Adapter booster may have wrench flats or spanner holes.
- On non-U.S. ordnance, top-down or side spanner holes on the adapter may indicate HE or WP (Figure 5.11).
- Fin assembly on the aft end of the motor.
- One or more venturis on the base of the motor.

Markings: Lime green, olive drab, or gray body with yellow and red markings are common. A brown band may be present on the motor. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: PD or BD fuzing.

General Safety Precautions:

- HE, frag, movement, WP, fire for the warhead and motor.
- Ejection, EMR, static for unfired motor.
- Chemical if burning, WP smoke is toxic.
- Safety precautions for fuze, if present.

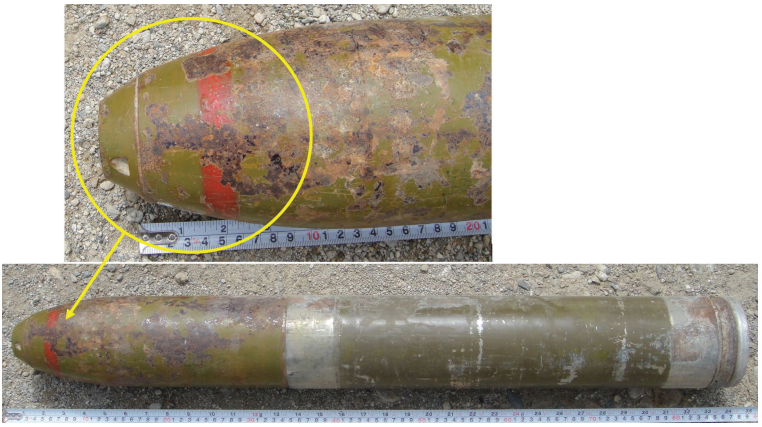

Figure 5.11 Chinese 107mm (4.21in) WP rocket with a nose fuze burster-adapter. Note the identifiable features that include red markings and the top-down spanner holes on the adapter. (Author's photographs.)

5. Category: Rocket. Group: Illumination: A dispenser-type warhead that ejects a parachute-suspended, pyrotechnic candle to illuminate an area at night. After firing, a time fuze functions at a predetermined time, initiating a low-explosive expelling charge, the pressure generated in the ogive or base overcomes the pressed or threaded baseplate or nose, ejecting the candle. The illumination candle may be ignited during ejection, or upon parachute deployment via a separate fuzing system (Figure 5.12). Candles can range in intensity from a few thousand to millions of candlepower.

General identification features include:

Materials and Appearance:

- Multi-piece, thin-skinned steel, aluminum, or fiberglass.
- Threaded or pressed nose cone that may be plastic.
- Spanner holes or shear pins that may be present on the nose cone or near the warhead–motor junction.
- Fin assembly on the aft end of the motor.
- One or more venturis on the base of the motor.

Markings:

- White, green, or gray body with black, red, and brown markings are common.
- The umbrella-like symbol (see Figure 4.27) is often used to identify illumination munitions for all ordnance categories.
- A brown band may be present on the motor.
- Other colors, stamped or stenciled markings, and symbols may also be present.

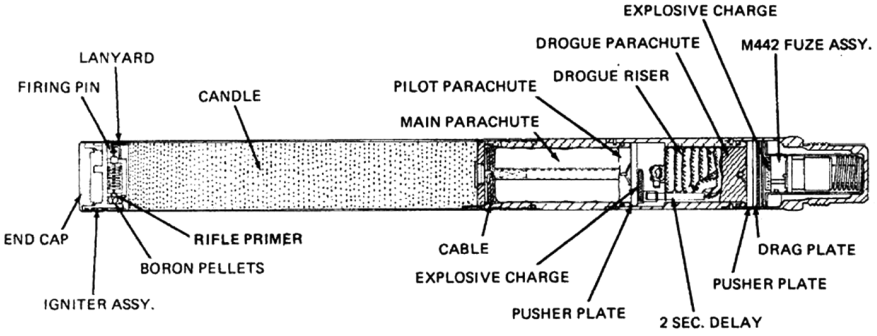

Figure 5.12 U.S. 2.75 inch, M257 multi-fuzed illumination rocket warhead. (From U.S. Military TM.)

Common Fuze Configurations: MT, ET, and PTTF fuzing.

General Safety Precautions:

- Movement, fire, ejection for the warhead.
- HE, frag, ejection, EMR, static for an unfired motor.
- Explosively ejected payload offers substantial hazard.
- Chemical if burning as smoke is toxic.
- Do not look directly at a burning candle.
- Safety precautions for fuze, if present.

6. Category: Rocket. Group: Practice: Designed to fire with the same ballistic characteristics as the live rocket it mimics, minus the destructive effects. Some are full sized, while others are subcaliber rockets fired through modified weapon systems. Practice rockets may be solid metal, contain an inert filler such as gypsum and wax to simulate explosives weight, or powdered dye that bursts to leave a large mark when impacting a target. Other designs contain a live fuze with an explosive charge to propel chlorosulphonic acid (FS) or other spotting materials so the point of impact can be seen at great distance (Figures 5.1 through 5.3).

General identification features include:

Materials and Appearance:

- Construction features consistent with the rocket they are designed to imitate.
- Designed for cost savings and training on restrictive ranges, subcaliber practice rockets share no appearance similarities with the rocket they mimic.

Markings:

- Blue body with white or brown markings is common (Figure 5.3).
- Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: If fuzed, the fuze will be the same type employed on the rocket being imitated.

General Safety Precautions:

- Movement.
- Observe all applicable safety precautions for the live rocket until positive identification is made.
- HE, frag, ejection when a spotting charge is present.
- HE, frag, ejection, EMR, static for an unfired motor.
- Safety precautions for fuze, if present.
- Practice means practice, it does not mean inert.

7. Category: Rocket. Group: Drill and Dummy: Incapable of firing, these rockets are designed to be used for weapon system loading and unloading drills, display, or training and contain no energetic materials whatsoever.

General identification features include:

Materials and Appearance:

- Construction features generally consistent with the rocket they are designed to imitate.

Markings: Gold, black, or blue body with white markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: None.

General Safety Precautions:

- Movement, until positive identification is made.

Closing

All ordnance, including practice rockets, are inherently dangerous, and unfired rockets possess an ability to launch, requiring additional safety considerations. Until proven otherwise, always consider a rocket to be in a hazardous condition.

If unable to identify a rocket that appears to be over 100 years old, applying the information on older munitions from Chapter 13 may be helpful.

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Ordnance Category—Grenades
Hand, Rifle, and Projected

6

The young man knows the rules, but the old man knows the exceptions.
Oliver Wendell Holmes

Introduction

Thousands of different grenade designs have been manufactured over the years. With so many designs, many of which are culturally influenced, it is impossible to cover every grenade. As such, the rules associated with shape, construction features, materials, and designs are focused on throughout this chapter, as they provide constants from which to begin the identification process. Detecting an exception to an established rule is often the key to positively identifying a grenade.

An important consideration associated with ordnance designs is the answer to "why was this munition made?" Ordnance design is the result of solving a tactical problem encountered on the battlefield. One fundamental of offensive or defensive combat operations is overlapping coverage from different weapon systems. Otherwise, coverage gaps or dead-space occur offering an enemy tactical cover as they identify and exploit these gaps. The history of modern grenades serves as an excellent example from which to explain how something as straight-forward as a hand grenade has evolved over the last 120 years.

Grenades date back to the 1600s when specially trained assault troops known as "grenadiers" threw softball-sized, iron balls filled with black powder and fitted with a manually lit fuze at the enemy. As these grenades were heavy, difficult to throw long-distances, and possessed fuses that were hard to ignite; a grenadier's job was dangerous. By the beginning of WWI, hand grenade designs became more conducive for throwing and fuzing was made very simplistic. As such, the training required was minimal and specialized troops were no longer necessary as grenades could be thrown by most soldiers. In this chapter, grenades developed during the 20th Century are covered. Chapter 13 covers pre-1900 hand grenades.

During the 20th century, a new type of grenade launched from a rifle and designed to cover the tactical gap between maximum hand grenade and minimum mortar ranges was fielded. Rifle grenades would be the grenadiers' primary weapon for many years across many countries. By the 1950s a more efficient delivery system for grenadiers was developed, circumventing the requirement to modify a rifle. Fired from what appears to be an oversized shotgun, projected grenades possess all of the characteristics of a projectile. Since they were designed to be deployed by grenadiers, these munitions are classified under the grenade category, which is an important caveat when researching an unknown munition with projectile-like characteristics.

Under "Grenades" there are three distinctly different category-types, shown in Appendix A, logic tree 2. In order to cover all three in a succinct manner, grenades are covered in the order they were developed:

1. Hand grenade
2. Rifle grenade
3. Projected grenade

Hand Grenades

Hand grenades are munitions designed to be manually armed and thrown by a single person. With a variety of fuzes available, hand grenades may function via preset time delay or upon impact. Some are equipped with extended handles for leverage that may also house a means of orientation such as a parachute that deploys after being thrown. Due to the number of hand grenades manufactured, their availability to most soldiers, and relatively small size, grenades are commonly recovered outside military control.

Key Identification Features for Hand Grenades

Ranging in size from a golfball to a one-liter bottle, the manner in which hand grenades are deployed offers the best identification features. For example, hand grenades designed in countries with popular sports involving throwing a ball; such as baseball or cricket, tend to produce somewhat oval-shaped grenades (Figures 6.1 and 6.2). However, soldiers from countries without such popular sports may not develop good throwing fundamentals in their youth. Accordingly, designs with features such as a stick are used to increase leverage and thus range (Figure 6.2). Grenade bodies come in many shapes, sizes, and configurations. Many have internal serrations and a smooth outer appearance, or plastic body that resembles children's toys or items used by paintball enthusiasts (Figures 6.6 and 6.8). See Appendices D and E for information on marking schemes.

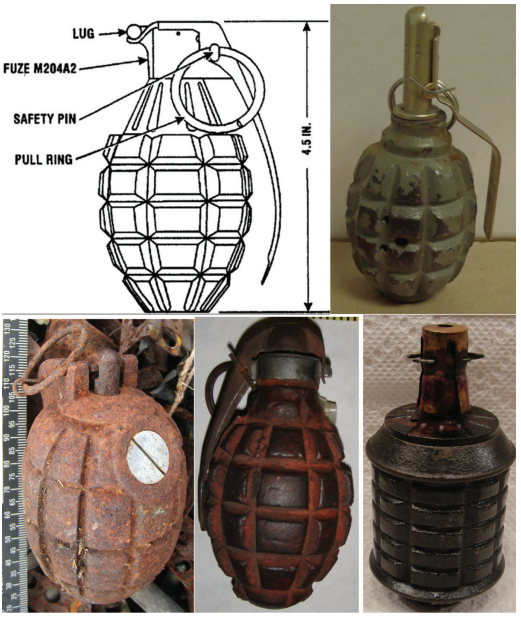


Figure 6.1 One of the most recognizable designs referred to as "Pineapple" grenades. Top left to right: U.S. MK2, Russian F-1. Bottom left to right: British "Mills Bomb," French F-1, and Japanese Type 97 (From U.S. Military TM, and author's photographs.)

Figure 6.2 Top: German "Egg-Type" fragmentation hand grenades. Bottom: German Model 24 blast grenade known as a "stick grenade" or "Potato Masher." (Author's photograph.)

Hand grenades can be smaller than a golfball (1.5" or 38mm) and are usually not much larger than a baseball (3.3" or 84mm), allowing the average person to throw them a distance greater than the hazards produced by the grenade. Larger grenades usually have a specific application, which take into consideration the associated range limits.

The Seven-Step Practical Process Applied to Hand Grenades

Examples of different designs, features, color codes, markings, and construction features are provided throughout this chapter.

Step 1: Gather Information, Approach, and Initial Inspection:

Attempt to identify from a safe distance with binoculars. Approach at a 45° angle from the rear, avoiding venturis and fuze sensing elements.

With sketch pad and camera, document identifying features including handles, fins, leaking material, color codes, stamped markings, construction features, damage, signs of tampering or modification. Measure the width and length of each component.

The three fastest means of researching an unknown hand grenade are:

1. The diameter at the largest section of the body
2. The overall length
3. The design and materials used on the fuze

Step 2: Determine Fuze Group, Type, and Condition:

Many hand grenade fuzes are direct-armed when a safety pin, clip, cap, or string is removed. If the fuze is damaged, pins have been removed, or alterations have been made, it is considered armed. If visible, measurements for the fuze are taken separately from the munition.

Step 3: Determine Ordnance Category:

The category "hand grenade" is covered throughout this section.

Step 4: Determine Ordnance Group:

The identifiable characteristics associated with each hand grenade group are covered throughout this section.

Step 5: Determine if Munition was Deployed:

Inspect the grenade for impact-related damage; missing pins, clips, caps, or string.

Step 6: Determine Safety Precautions:

Safety precautions for each hand grenade group are covered in this chapter. Once identified, these precautions must be adhered to.

Step 7: Research Literature and Identify the Munition:

Apply the totality of measurements, color codes, stamped markings, and construction features to determine the group, and positively identify the munition and fuzing configuration.

In some literature, submunitions are referred to as "grenades." Review the key identification features, refer to Chapter 9 to deconflict similar designs.

Groups

For congruency, hand grenades are divided into these groups:

a. Blast
b. Fragmentation (frag)
c. HEAT
d. Bursting smoke
e. Burning smoke
f. Riot control
g. Illumination
h. Incendiary
i. Practice

1.a. Category: Hand Grenade. Group: Blast: Classified as "offensive" grenades as they are deployed by troops moving forward. Designed to produce blast and overpressure effects with minimal fragmentation, so troops deploying them are not injured by fragments from grenades they have thrown.

Most blast grenades contain between 1oz to 6oz (28gr to 170gr) of explosive housed in a soft or thin-skin body. The basic configuration of a blast grenade is the same as a fragmentation grenade without a heavy fragmentation liner (Figures 6.3 through 6.5).

General identification features include:

Materials and Appearance:

- Lightweight materials such as thin aluminum, cardboard, tarpaper, or plastic.
- External fuze with "spoon" held in place by a safety pin.
- A configuration able to accommodate a fragmentation sleeve (Figure 6.4).
- "Stick grenades" with wooden or light metal handle, housing a pull-friction fuze.
- Some designs have a thin plastic body covering a fragmentation liner and resemble those used by paintball enthusiasts or children's toys.

Markings: Black or green body with yellow markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

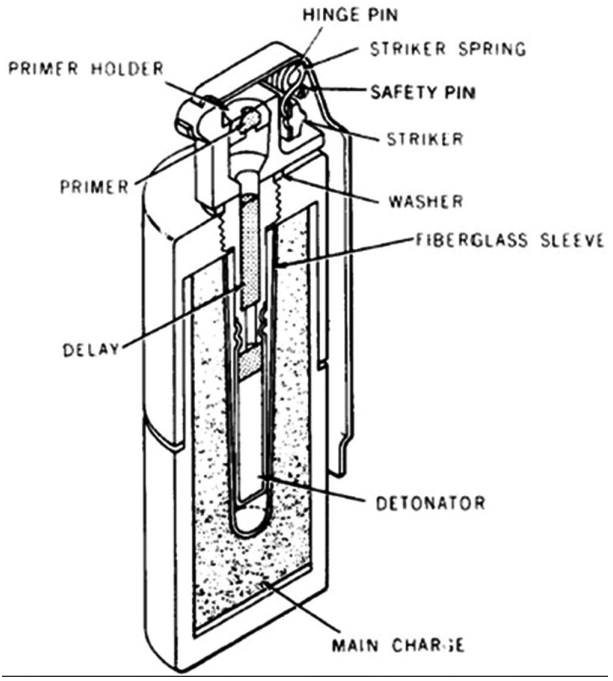


Figure 6.3 U.S. MK 3 with tarpaper-like body. An ejection charge pops the fuze off and away from the grenade before it detonates. (From U.S. Military TM.)

Figure 6.4 Belgian NR 7/8 with removable fragmentation sleeve. (Author's photograph.)

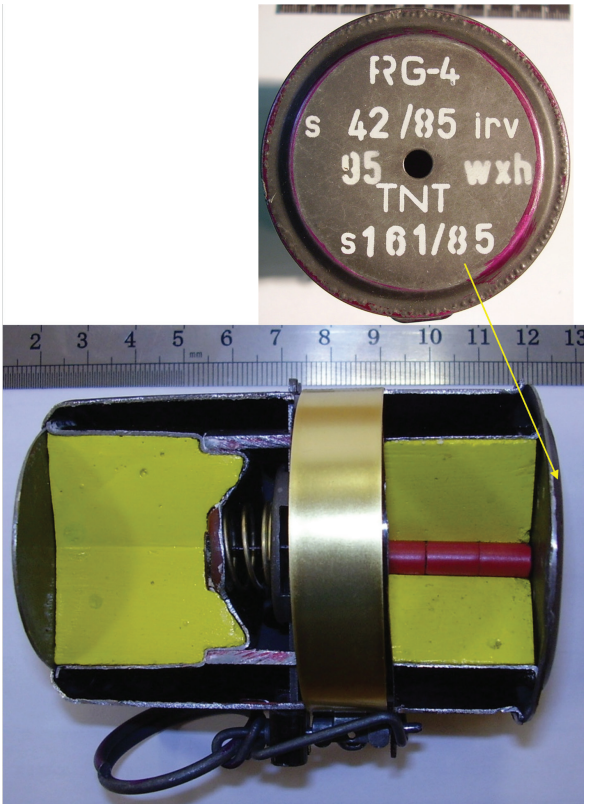


Figure 6.5 Czech Republic RG4 with an internal all-way-acting impact fuze. There is a Russian version with the same name. (Author's photograph.)

Common Fuze Configurations: Direct armed, pyrotechnic delay fuze is most common. May incorporate direct armed electrical, or mechanical impact fuzing.

General Safety Precautions:

- HE, movement.
- Safety precautions for fuze, if present.

1.b. Category: Hand Grenade. Group: Fragmentation (Frag): Classified as "defensive" grenades as they are deployed by troops in defensive positions. Designed to produce blast, frag, and overpressure effects, most contain between 1oz to 8oz (28gr to 227gr) of high explosive. In order to maximize fragmentation, body configurations include serrated cast bodies, micro-engraved steel, coiled-spring fragmentation sleeve, or layers of bearings suspended in plastic (Figures 6.5 through 6.7). Some designs are small, others have the classic "pineapple" appearance (Figures 6.1 and 6.2).

Figure 6.6 Top: Smooth outer body may hide well-designed fragmentation. Left to right: Austrian HGR 85, Montenegrin M50P3 and M93. Bottom: Left to right: Austrian HDGR 73 (white), former-Yugoslavian BR-M91 (black), and a Czech Republic URG-86. (Author's photographs.)

Figure 6.7 U.S. M67 fragmentation grenade, cutaway to expose internal fragmentation. (Author's photographs.)

General identification features include:

Materials and Appearance:

- Externally or internally serrated iron or steel body of heavy construction.
- An external spring-like fragmentation sleeve.
- A plastic or sheet-metal outer cover concealing a fragmentation liner.
- External fuze with "spoon" held in place by a safety pin.
- "Stick grenades" with wooden or light metal handle, housing a pull-friction fuze.
- Some designs have a thin plastic body covering a fragmentation liner and resemble those used by paintball enthusiasts or children's toys (Figures 6.6 and 6.8).

Markings: Green, black, or white body with yellow or red markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Figure 6.8 X-ray is a viable tool for inspecting grenades. All grenades are displayed with x-ray on top, photograph below. Left to right: Japanese Type 97 with serrated cast body, former-Yugoslavian M85 with plastic body concealing fragmentation, U.S. M26 with coiled-spring fragmentation liner covered with smooth sheet-metal, and Belgian M72 with plastic body concealing fragmentation. (X-ray courtesy of Kristin Lejeune; author's photograph on bottom.)

Common Fuze Configurations: Direct armed, pyrotechnic delay fuze is most common. May incorporate direct armed electrical, or mechanical impact fuzing.

General Safety Precautions:

- HE, frag, movement.
- Safety precautions for fuze, if present.

1.c. Category: Hand Grenade. Group: HEAT: Contains a shaped charge warhead to defeat armored and other hardened targets. In order for the shaped charge to form, a standoff is needed, as is a larger explosive charge. As such, HEAT grenades tend to be larger than other groups, containing 6 to 24oz (171 to 680gr) of HE, a means of stabilization, and standoff. All of which provide unique features to assist in identifying a HEAT grenade (Figure 6.9).

These grenades are not common, and the United States has not fielded a viable version, but many other countries have.

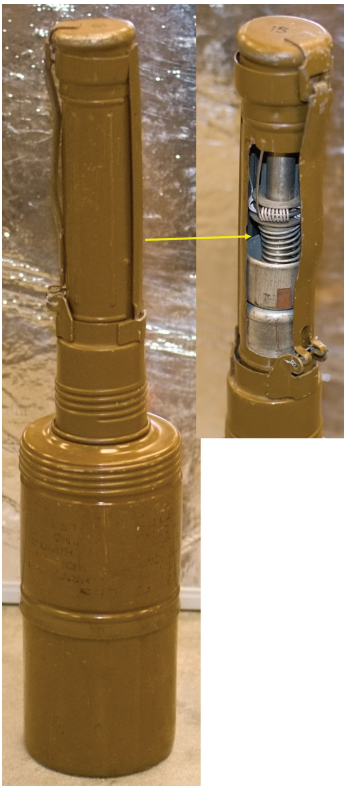


Figure 6.9 Russian RKG-3, HEAT grenade. The fuze is in the handle, and the mid-body break leaves the forward section hollow to provide standoff for the shaped charge. (Courtesy of Tom Conte.)

General identification features include:

Materials and Appearance:
- Light sheet-metal or plastic construction.
- May have a plastic body that opens like a clamshell to provide orientation during deployment.
- A break in the major diameter of the body, where explosives, cone, and standoff meet (Figure 6.9).
- Handle with deployable fins, parachute, a cloth-covered spring, or other means of orientation.
- A smooth outer appearance.
- Partially or completely internal fuze.

Markings: Green, brown, or black body with yellow, red, or black markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: BD, PIBD mechanical impact-initiated fuzing is common. Most fuzes are partially armed prior to being thrown, then armed when fins, parachute or other component deploys. If present, the Point Initiating (PI) element may be observable.

General Safety Precautions:
- HE, frag, movement, jet.
- Safety precautions for fuze, if present.

1.d. Hand Grenade, Bursting Smoke, WP: Designed to produce smoke for screening, marking; and fire for destroying targets. Bursting smokes contain White Phosphorus (WP) with a high explosive bursting charge that breaks the grenade body into pieces while dispersing the WP filler.

General identification features include (Figure 6.10):

Materials and Appearance:
- Solid, one-piece body of robust construction.
- Body may have external serrations.
- Size of a soda can or larger.
- External fuze with "spoon" held in place by a safety pin.
- Some designs resemble burning smokes in shape but lack the telltale emission holes consistent with burning smokes (Figure 6.11).

Markings: Lime green or gray body with yellow and red markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Figure 6.10 U.S. M34 Bursting Smoke, White Phosphorus (WP) grenade. The groove just above the tapered base is to affix the grenade to a rifle grenade tail-boom assembly. (Author's photograph.)

Figure 6.11 Left to right: U.S. M18 burning smoke grenade with four emission holes on top and (center) single hole on bottom, U.S. AN-M14 Incendiary Hand Grenade containing 1.6 pounds of TH3 thermate. (From U.S. Military TM and author's photographs.)

Common Fuze Configurations: Direct armed, pyrotechnic delay fuze is most common. May incorporate direct armed electrical, or mechanical impact fuzing.

General Safety Precautions:

- HE, frag, movement, WP, fire.
- Chemical if burning, WP smoke is toxic.
- Safety precautions for fuze, if present.

1.e. Category: Hand Grenade. Group: Burning Smoke: Contain pyrotechnic mixtures that burn to produce smoke in a variety of colors for signaling or screening. A small flame and hot gas are produced with the colored smoke, but the grenade body remains intact after functioning.

General identification features include (Figure 6.11):

Materials and Appearance:

- Light sheet-metal construction with smooth appearance.
- Size of a soda can or larger.
- External fuze with "spoon" held in place by a safety pin.
- Telltale emission holes for smoke to escape on top or bottom (Figure 6.11).
- Rolled or crimped edges.

Markings: Green body is common. The color on top, or a band will indicate the color of smoke produced. The color of the markings on the body may or may not match the color of smoke. Other colors or stamped markings may also be present.

Common Fuze Configurations: Direct armed, instantaneous fuze without a pyrotechnic delay is most common.

General Safety Precautions:

- Movement, fire.
- Chemical for burning white HC smoke, which is toxic in field concentrations.
- Safety precautions for fuze, if present.

1.f. Category: Hand Grenade. Group: Riot Control:

There are two types of riot control hand grenades, burning and bursting. Both contain CN, CS, CN1, or other pepper-like riot control agents. However, the manner in which the material is dispersed, concentration, and safety precautions are substantially different.

Type 1: Burning: Deployed in the same body configuration as many burning smoke grenades, these disperse riot control agents in the smoke generated by burning (Figure 6.11).

Type 2: Bursting: Designed to explosively disperse concentrated riot control agent, without producing smoke or burning. The hardened outer body fragments when the powdered agent is dispersed (Figure 6.12).

General identification features include:

Materials and Appearance:

Type 1: Burning: (Figure 6.11).

- Light sheet-metal construction with smooth appearance.
- Size of a soda can or larger.
- External fuze with "spoon" held in place by a safety pin.
- Telltale emission holes for smoke to escape on top, bottom, or both.
- Rolled or crimped edges.

Type 2: Bursting: Are usually round, about the size of a baseball or softball. The body may be hard rubber, bakelite plastic, or other hardened material. Filler plug and low-profile fuze may be present (Figure 6.12).

- Hard, smooth plastic body.
- Size of a baseball or larger.
- External fuze with a safety pin.
- Telltale filler hole for concentrated powder.

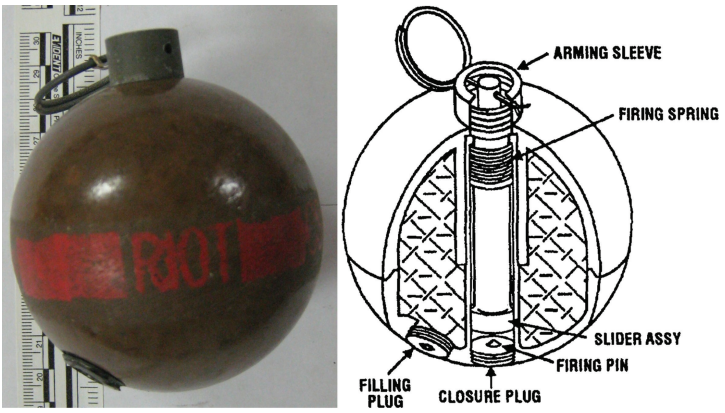


Figure 6.12 U.S. M25A1 bursting, riot control hand grenade. (From U.S. Military TM and author's photograph.)

Markings:

Type 1: Burning: Gray body with red bands and markings are common. Color codes or markings are required to differentiate from colored smoke grenades.

Type 2: Bursting: Body colors vary depending on materials used. A black rubber body, and brown or gray bakelite plastic body with red bands or markings are common.

Common Fuze Configurations:

- Burning: Direct armed, instantaneous fuze without a pyrotechnic delay is most common
- Bursting: Direct armed, pyrotechnic delay fuze is most common.

General Safety Precautions:

Type 1: Burning:

- Movement, fire, and chemical.
- Safety precautions for fuze, if present.

Type 2: Bursting:

- HE, frag, movement, and chemical.
- Safety precautions for fuze, if present.

1.g. Category: Hand Grenade. Group: Illumination: Contain pyrotechnic mixtures to signal or illuminate an area. The design in Figure 6.13 consists of two sheet-metal cups pressed together and sealed. When the fuze functions, the two halves are separated as the pyrotechnic composition ignites.

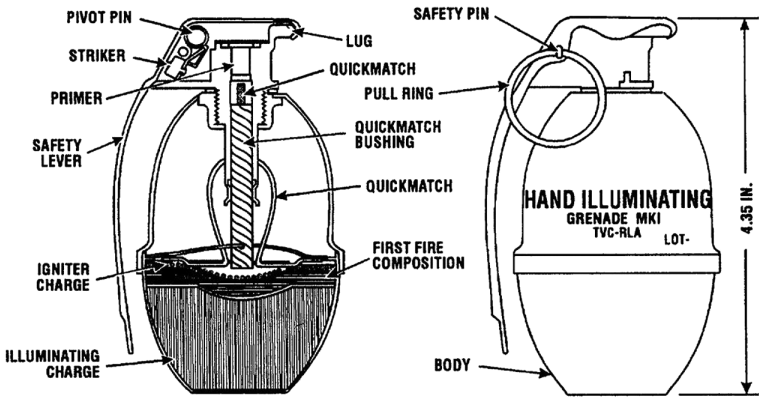


Figure 6.13 U.S. MK1 grenade burns at 55,000 candlepower, illuminating an area 200 meters in diameter, and poses a significant fire hazard. (From U.S. Military TM.)

General identification features include:

Materials and Appearance:
- Light sheet-metal construction with smooth appearance.
- Size of a baseball or smaller.
- External fuze with "spoon" held in place by a safety pin.
- A seam near the middle of the body.

Markings:
- White or green body with black or white markings are common.
- An umbrella-like symbol (see Chapter 4, Figure 4.28).
- Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: Direct armed, pyrotechnic delay fuze is most common. Many designs do not incorporate a delay and function immediately after being thrown.

General Safety Precautions:
- Movement, fire.
- Chemical if burning as smoke is toxic.
- Do not look directly at a burning candle.
- Chemical if burning as smoke is toxic.
- Safety precautions for fuze, if present.

1.h. Category: Hand Grenade. Group: Incendiary: Contain thermite or thermate mixtures designed to burn at approximately 4000°F and destroy equipment by melting or burning.

General identification features include (Figure 6.11):

Materials and Appearance:
- Light sheet-metal construction with smooth appearance.
- Similar in size and configuration as many burning smoke grenades, but lack the telltale smoke emission holes.
- Size of a soda can or larger.
- External fuze with "spoon" held in place by a safety pin.
- May or may not have rolled or crimped edges.

Markings: Red body with black markings are common. Other colors, stamped or stenciled markings, and symbols may also be present on the grenade.

Common Fuze Configurations: Direct armed fuze with no delay is most common. Most designs have the same external appearance as grenade fuzes with time delays for safe separation. Correct identification is key.

General Safety Precautions:

- Movement, fire.
- Chemical if burning as smoke is toxic.
- Do not look directly if burning.
- Safety precautions for fuze, if present.

1.i. Category: Hand Grenade. Group: Practice: Designed to resemble and be deployed in the same manner as the live grenade they mimic, minus the destructive effects. "Practice" does not mean safe or inert, and many practice grenades contain significant hazards, including live fuzing and pyrotechnic spotting charges.

General identification features include (Figures 6.14 and 6.15):

Materials and Appearance:

- Construction features consistent with the projectile they are designed to imitate.
- External fuze with "spoon" held in place by a safety pin.

Markings: Blue body with brown markings are common. However, black bodies with white markings, yellow bodies with black markings, and other color combinations are also common.

Common Fuze Configurations: Direct armed, pyrotechnic delay fuze is most common.

General Safety Precautions:

- Movement.
- Observe all applicable safety precautions for the live grenade until positive identification is made.
- Safety precautions for fuze, if present.
- Practice means practice, it does not mean inert.

Rifle Grenades

Rifle grenades were devised to cover the tactical range beyond hand grenades. Fuzes may be partially armed by the removal of a pin or involve a

Figure 6.14 South Korean K417 Practice Grenade with yellow spotting charge (note damage to fuze housing). (Author's photograph.)

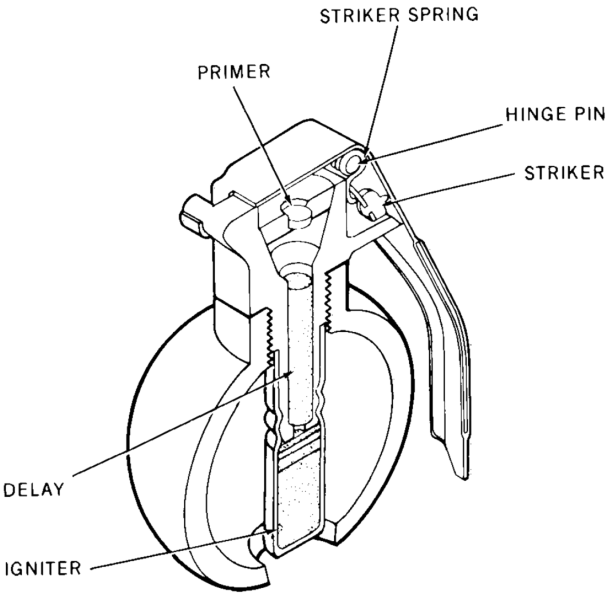


Figure 6.15 U.S. M69 Practice Grenade with a live fuze. The hole in the base of the empty body allows the energy to vent. (From U.S. Military TM.)

multifaceted arming sequence taking place during flight, or a combination of both. There are three primary designs used to deploy rifle grenades munitions:

1. An adapter is placed on the end of a rifle in which the rifle grenade is placed. When the rifle is fired, the gas produced by the firing of a bullet, which "passes through" the grenade capturing the gas behind it, propels the munition (Figure 6.16).
2. The gas produced by the firing of a blank cartridge is captured inside the stabilizer tube assembly, propelling the rifle grenade. Some designs incorporate a "bullet trap" to catch the bullet while transferring the energy further propelling the rifle grenade, negating the requirement to use a blank (Figures 6.17, 6.20, and 6.23).
3. An adapter is placed on the end of a rifle in which the rifle grenade is placed. When the rifle is fired, the gas produced by the blank cartridge propels the munition (Figure 6.18). Some cartridges fire a wooden bullet.

Key Identification Features

The manner in which they are deployed offers the best identification features for rifle grenades. Design 1 has the unique feature of a hole running through the middle of the munition (Figure 6.16). Design 2 includes a hollow stabilizer tube assembly, lacking the emission holes consistent with a mortar or recoilless rifle projectile, or the venturi of a rocket (Figure 6.17). Design 3 is spin stabilized with lands and grooves present.

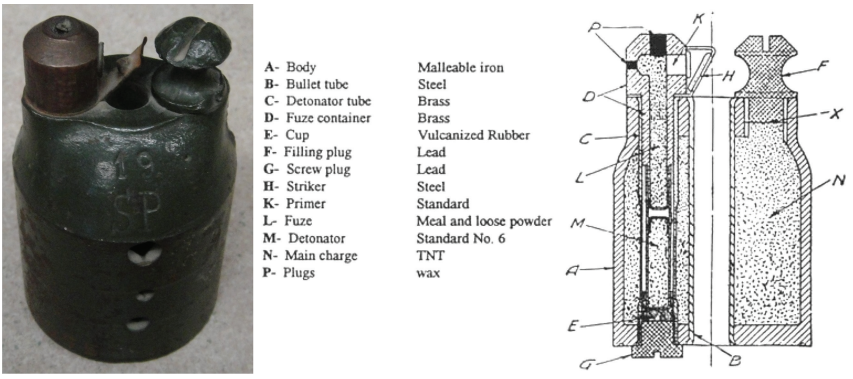

A- Body — Malleable iron
B- Bullet tube — Steel
C- Detonator tube — Brass
D- Fuze container — Brass
E- Cup — Vulcanized Rubber
F- Filling plug — Lead
G- Screw plug — Lead
H- Striker — Steel
K- Primer — Standard
L- Fuze — Meal and loose powder
M- Detonator — Standard No. 6
N- Main charge — TNT
P- Plugs — wax

Figure 6.16 French WWI-era Vivien Bessiere (VB) Rifle Grenade. (From U.S. Military TM and author's photograph.)

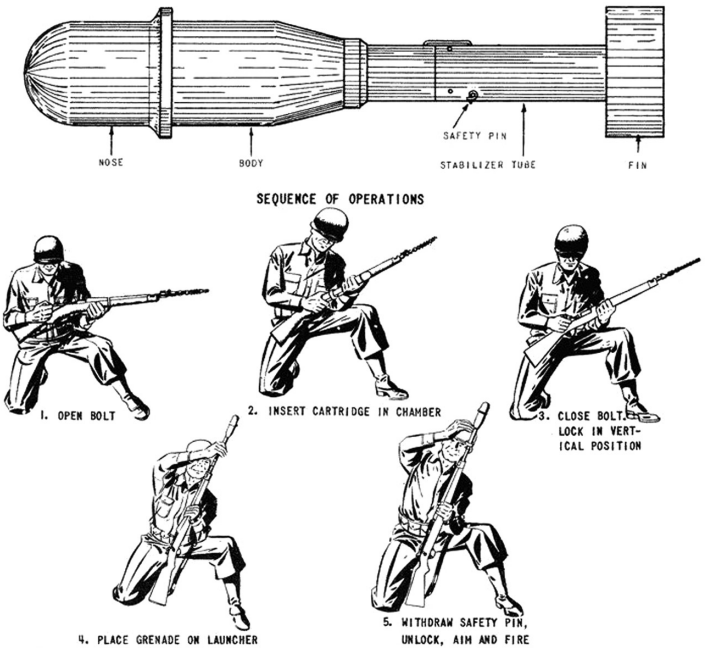


Figure 6.17 U.S. M9A1, HEAT Rifle Grenade sequence of fire. (From U.S. Military TM.)

Figure 6.18 German, WWII-era, spin stabilized rifle grenades. Left to right: Gewehr-Sprenggranate HE-Frag, and Gross Gewehr Panzergranate HEAT, Rifle Grenades. (Author's photographs.)

When inspecting a possible rifle grenade, the most effective means of identification may not be what is present, but rather what is not. See Appendices D and E for information on marking schemes.

Rifle Grenade Sections

Stabilizer tube assembly. Sometimes referred to as a tail-boom, this section fits over the barrel of a rifle, contains fins toward the base, and attaches to the warhead or hand grenade at the forward end. Depending on design, a bullet trap may be in the forward end, and a fuze may be located between the stabilizer tube assembly and the warhead (Figure 6.17).

Warhead or body. Terms often used interchangeably. For rifle grenades, the body or warhead is the section containing chemical agents, high explosives, or other energetic materials.

The Seven-Step Practical Process Applied to Rifle Grenades

Examples of different designs, features, color codes, markings, and construction features are provided throughout this section.

Step 1: Gather Information, Approach, and Initial Inspection:

Attempt to identify from a safe distance with binoculars. Approach at a 45° angle from the rear to avoid potential hazards.

With sketch pad and camera, document identifying features including handles, fins, rotating bands, leaking material, color codes, stamped markings, construction features, damage, signs of tampering or modification. Also note and measure the location, length, and width of each component.

The three fastest means of researching an unknown rifle grenade:

1. The diameter at the largest section of the body.
2. The overall length.
3. A hollow stabilizer tube assembly lacking a venturi consistent with a rocket, or the ignition holes consistent with mortar and recoilless rifle projectiles.

Step 2: Determine Fuze Group, Type, and Condition:

Some rifle grenade fuzes are direct-armed when a safety pin or clip is removed; others must be fired to arm. If the fuze is damaged, pins have been removed, or alterations have been made, it is considered armed. If visible, measurements for the fuze are taken separately from the munition.

Step 3: Determine Ordnance Category:

The category "rifle grenade" is covered throughout this section.

Step 4: Determine Ordnance Group:

The identifiable characteristics associated with each rifle grenade group is covered throughout this section.

Step 5: Determine if Munition was Deployed:

Inspect the grenade for impact-related damaged; missing pins, clips, caps, or string.

Step 6: Determine Safety Precautions:

Safety precautions for each rifle grenade group are covered in this section. Once identified, these precautions must be adhered to.

Step 7: Identify the Munition:

Apply the totality of measurements, color codes, stamped markings, and construction features to determine the group, and positively identify the munition and fuzing configuration.

Groups

For congruency, rifle grenades are divided into these groups:

a. Fragmentation
b. HEAT
c. Bursting smoke
d. Burning smoke (includes colored smoke and riot control).
e. Illumination
f. Practice

2.a. Category: Rifle Grenade. Group: Fragmentation: May consist of a defensive hand grenade fixed to a rifle grenade tail-boom, or a stand-alone design (Figure 6.19). Most contain between two to eightoz (57 to 227gr) of high explosive. In order to maximize frag, body configurations include serrated cast bodies, micro-engraved steel, fragmentation sleeves, or layers of bearings suspended in plastic. Incendiary materials may be added to provide an anti-material effect.

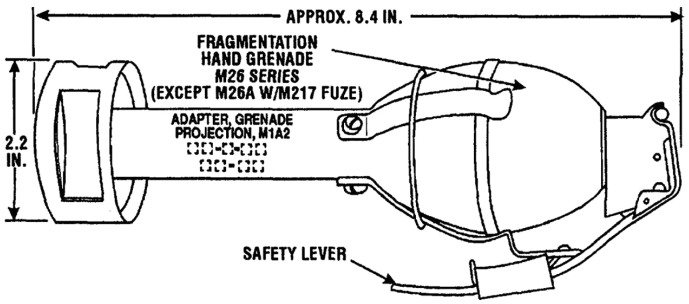


Figure 6.19 U.S. MK26 Fragmentation Grenade mounted on an M1-Series "Grenade Projection Adapter." (From U.S. Military TM.)

General identification features include (Figures 6.16, 6.18, and 6.19):

Materials and Appearance:

- ID features consistent with a fragmentation hand grenade with the addition of a stabilizer tube assembly.
- Depending on design, external or internal fuze.
- Hollow stabilizer tube assembly lacking a venturi or the ignition holes.
- Grenade bodies with internal serrations but possibly a smooth outer appearance.
- Some designs have a thin plastic body covering a fragmentation liner and resemble those used by paintball enthusiasts or children's toys.

Markings: Green or black body with yellow or red markings are common. Other colors, stamped or stenciled markings, and symbols may also be present on the body, fuze, or tail-boom/stabilizer tube assembly.

Common Fuze Configurations: PD, BD, or direct armed pyrotechnic delay fuzing.

General Safety Precautions:

- HE, frag, movement.
- Safety precautions for fuze, if present.

2.b. Category: Rifle Grenade. Group: HEAT: Contain a shaped charge warhead to defeat armored and other hardened targets. In order for the shaped charge to form and maximize penetration, HEAT rifle grenades must have a means of orientation and stabilization, contain about 6 to 24oz (171 to 680gr) of HE, and a standoff. All of these characteristics provide unique features to assist in identifying an unknown munition (Figures 6.17, 6.18, and 6.20).

HEAT rifle grenades provide infantrymen with an anti-armor capability that can be deployed at a reasonable standoff distance. Unlike HEAT hand grenades, which are uncommon, HEAT rifle grenades are very common.

General identification features include:

Materials and Appearance:

- A break in the major diameter of the body where the explosives, cone, and standoff meet (Figures 6.17, 6.18, and 6.20).
- Partially or completely internal fuze.
- Hollow stabilizer tube assembly lacking a venturi or ignition holes.

Figure 6.20 Belgian RFL-40 HEAT rifle grenade with bullet trap. (Author's photograph.)

Markings: Green or black body with yellow, black, and red markings are common. Other colors, stamped or stenciled markings, and symbols may also be present on the body, fuze, or tail-boom/stabilizer tube assembly.

Common Fuze Configurations: BD and PIBD-spitback, PIBD-PE fuzes that are direct-armed or partially armed prior to firing and complete the arming process during flight are common.

General Safety Precautions:

- HE, frag, movement, jet.
- Many PIBD fuzing systems incorporate PE. Apply PE, EMR, and static safeties until PE is conclusively ruled out.
- Safety precautions for fuze, if present.

2.c. Category: Rifle Grenade. Group: Bursting Smoke, WP: Designed to produce smoke for screening, marking; and fire for destroying targets. Bursting smokes contain White Phosphorus (WP) and a HE bursting charge that breaks the grenade body into pieces while dispersing the WP filler. Configurations include a hand grenade (Figure 6.10) mounted on a tail-boom assembly as seen in Figure 6.19, or a purpose-built rifle grenade as seen in Figure 6.21.

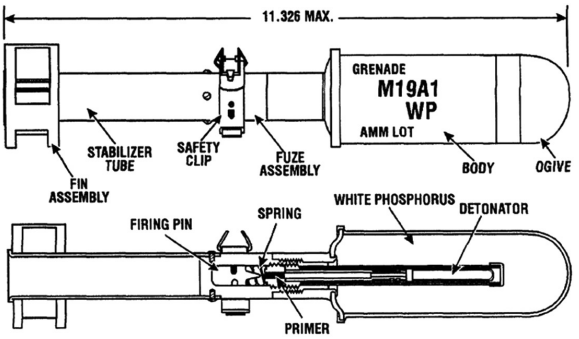


Figure 6.21 U.S. M19A1 Bursting Smoke, White Phosphorus Rifle Grenade. (From U.S. Military TM.)

General identification features include:

Materials and Appearance:

- A stabilizer assembly attached to an M34 hand grenade (Figure 6.10). The groove near the base of the grenade is designed for this application.
- Or, a light sheet-metal construction with smooth appearance.
- Partially or completely internal fuze.
- Some designs resemble a burning smoke in shape and size but lack the telltale emission holes.
- Hollow stabilizer tube assembly lacking a venturi or ignition holes.

Markings: Lime green body with yellow markings is common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: Pyrotechnic delay, or PD, BD fuzes that are direct-armed or partially armed prior to firing and complete the arming process during flight are common.

General Safety Precautions:

- HE, frag, movement, WP, fire.
- Chemical if burning, WP smoke is toxic.
- Safety precautions for fuze, if present.

2.d. Category: Rifle Grenade. Group: Burning Smoke and Riot Control: Contain pyrotechnic mixtures that burn to produce smoke in a variety of colors for signaling or screening. A small flame and hot gas are produced with the colored smoke; however, the grenade body remains intact after functioning.

Configurations include a hand grenade (Figure 6.11) mounted on a tail-boom assembly as seen in Figure 6.19, or a purpose-built rifle grenade as seen in Figure 6.22. Most riot control rifle grenades work the same with the addition of CS or CN to the smoke mixture and thus not afforded a section of their own.

General identification features include:

Materials and Appearance:

- A stabilizer assembly attached to an M18-style hand grenade. The rolled or crimped edge base of the grenade is designed for this application.
- Or, a light sheet-metal construction with smooth outer appearance.
- A completely internal fuze.
- Telltale emission holes on bottom of body section so smoke can escape.
- Rolled or crimped bottom of body section.
- Hollow stabilizer tube assembly lacking a venturi or ignition holes.

Markings: Gray or green body with white, yellow, or red markings are common. The color on the bottom of the body where it meets the stabilizer tube or a band on the body may indicate the color of smoke or riot control agent produced. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: Pyrotechnic delay, or BD, direct armed, or partially armed fuzes that complete the arming process during flight are common.

Figure 6.22 U.S. M23 Burning Smoke Rifle Grenade. Note vent holes and color on base of warhead section. (Author's photographs.)

General Safety Precautions:

- Movement, fire.
- Chemical for burning riot control agents, and white HC smoke, which is toxic in field concentrations.
- Safety precautions for fuze, if present.

2.e. Category: Rifle Grenade. Group: Illumination: A dispenser that ejects a parachute-suspended, pyrotechnic candle to illuminate an area at night. After firing, a time fuze functions at a preset time, initiating a low-explosive expelling charge. The pressure generated overcomes the pressed or threaded nose or tail-boom, ejecting the payload. The illumination candle may be ignited during ejection, or upon parachute deployment via a separate fuzing system. There are also star-cluster designs for signaling that do not have a parachute but provide substantial illumination while falling quickly to the ground.

General identification features include (Figure 6.23):

Materials and Appearance:

- Light sheet-metal construction with smooth appearance.
- Flat nose with no ogive and a crimped-on cap.
- Internal fuzing.
- May have observable time settings.
- Hollow stabilizer tube assembly lacking a venturi or ignition holes.

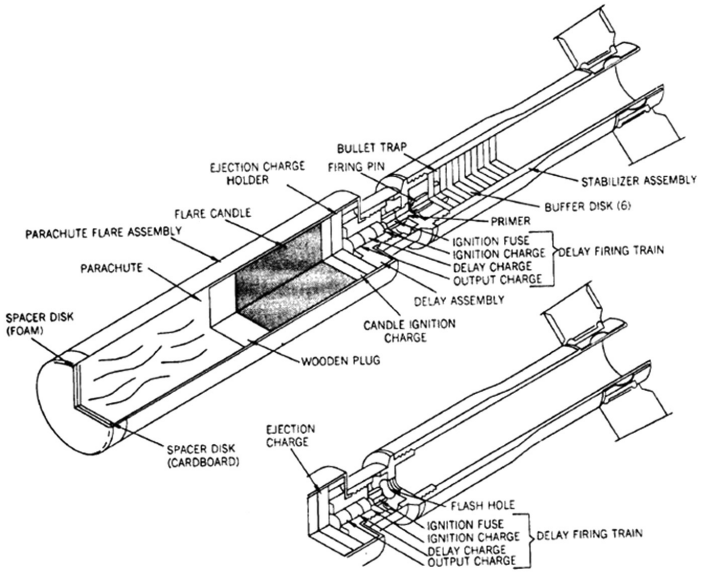


Figure 6.23 Illumination rifle grenade with bullet trap. (From U.S. Military TM.)

Markings: White or green body with black or white markings and a white band are common. As is the umbrella-like symbol seen in Chapter 4, Figure 4.28.

Common Fuze Configurations: PTTF fuzing to deploy the payload. Candle may be ignited during deployment, or during parachute deployment via a mechanical pull-initiated fuze.

General Safety Precautions:

- Movement, fire, ejection.
- Explosively ejected payload offers substantial hazard.
- Chemical if burning as smoke is toxic.
- Do not look directly at a burning candle.
- Safety precautions for fuze, if present.

2.f. Category: Rifle Grenade. Group: Practice: Designed to resemble and be deployed in the same manner as the live grenade they mimic, minus the destructive effects. "Practice" does not mean safe or inert, and many practice grenades contain significant hazards, including live fuzing and pyrotechnic spotting charges.

General identification features include:

Materials and Appearance:

- Construction features consistent with the projectile they are designed to imitate.
- External fuze with "spoon" held in place by a safety pin.
- Hollow stabilizer tube assembly lacking a venturi or ignition holes.

Markings: Blue body with brown markings are common. However, black bodies with white markings, yellow bodies with black markings, and other color combinations are also common.

Common Fuze Configurations: Direct armed or pyrotechnic delay fuzing is most common.

General Safety Precautions:

- Movement.
- Observe all applicable safety precautions for the live grenade until positive identification is made.
- Safety precautions for fuze, if present.
- Practice means practice, it does not mean inert.

Projected Grenades

Projected grenades were devised to increase the fire power at the squad level and more effectively cover the tactical range between hand grenades and mortars. Projected grenade configurations meet all three defining factors of a projectile provided in Chapter 4:

1. The body being projected is fired down a barrel or tube by gas pressure generated from a propellant charge.
2. The propellant charge is the munition's primary means of deployment.
3. The body being projected does not have an attached motor, or other primary means of propulsion.

Projected grenades are categorized by tactical design, rather than practical application. Made to be deployed by infantry grenadiers, they are classified as "ammunition for grenade launchers" and categorized as "projected grenades." All of which is a deviation from any conventional categorization system and something to note for research considerations. See Appendices D and E for information on marking schemes.

Key Identification Features

Unlike projectiles, projected grenades are usually constructed of light materials such as aluminum and plastic. There are more robust designs with copper rotating bands and others that retain their propellant during flight. Since they are not designed to travel great distances, projected grenades tend to have an overall lighter appearance. When a projectile with a diameter of 25mm to 40mm is being researched, consider the possibility of a projected grenade.

Projected Grenade Sections

Ogive: Projected grenades usually have a flat or rounded ogive. Many 40mm designs have a unique gold anodized ogive.
Bourrelet: The section between the ogive and body.
Body: The cylindrical section between the forward bourrelet and rotating band.
Rotating Band and Gas-Check Band: As a spin-stabilized munition, projected grenades have rotating or gas-check bands. Gas-check bands are sometimes referred to as "rotating bands" in reference materials; however, they are significantly different in appearance from a conventional copper rotating band (Figures 6.24 and 6.25). There are also prescored designs Figure 6.26).

Figure 6.24 Left: Chinese 35mm, DFJ87 AT/AP. Right: U.S. 40mm, M433 HEDP. Both of these munitions are configured with a shaped charge and body designed for fragmentation. (Author's photographs.)

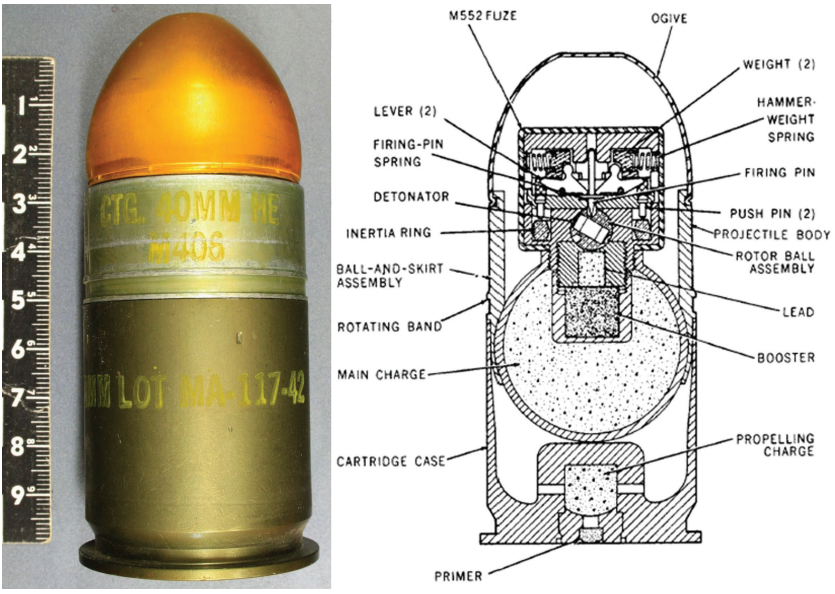


Figure 6.25 U.S. 40mm, HE, M406 with gas-check bands. (From U.S. Military TM and author's photograph.)

Figure 6.26 Russian 40mm, HE, VOG-25 series projected grenades. (Author's photograph.)

Base: Many features associated with the base of a projected grenade can assist in the identification process. Base configurations can be solid, recessed, contain propellant, or a base fuze ignited during firing.

The Seven-Step Practical Process Applied to Projected Grenades

Examples of different designs, features, color codes, markings, and construction features are provided throughout this section.

Step 1: Gather Information, Approach, and Initial Inspection:

Attempt to identify from a safe distance with binoculars. Approach at a 45° angle from the rear.

With sketch pad and camera, document identifying features including: rotating bands, leaking material, color codes, stamped markings, construction features, damage, signs of tampering or modification. Also note the location and width of the rotating bands, gas-check bands, obturator ring, and crimping rings. Measure the width and length of each component.

The three fastest means of identifying an unknown projected grenade:

1. A diameter at the bourrelet, between 25 to 40mm
2. The overall length
3. The design and material used on the gas-check or rotating band

Step 2: Determine Fuze Group, Type and Condition: If a projected grenade has been deployed (step 5), the fuze is considered armed. If the fuze is damaged or any alterations have been made, it is considered armed. If visible, measurements for the fuze are taken separately from the munition.

Step 3: Determine Ordnance Category:

Grenades designed to be fired from a grenade launcher, categorized as "projected grenade" are covered throughout this section.

Step 4: Determine Ordnance Group:

The identifiable characteristics associated with each projected grenade group are covered throughout this section.

Step 5: Determine if Munition was Deployed:

Inspect for impact-related damage; soot on the base from propellant charge and scoring on rotating or gas-check bands.

Step 6: Determine Safety Precautions:

The safety precautions for each projected grenade group are covered in this section. Once identified, these precautions must be adhered too.

Step 7: Identify the Munition:

Apply the totality of measurements, color codes, stamped markings, and construction features to determine the group, and positively identify the munition and fuzing configuration.

Groups

For congruency, projected grenades are divided into these groups:

a. HE-fragmentation
b. Bounding HE-fragmentation
c. High Explosive Dual Purpose (HEDP)
d. Burning smoke (includes colored and riot control)
e. Illumination
f. Practice

3.a. Category: Projected Grenade. Group: HE-Fragmentation: As projected blast grenades are virtually nonexistent, projected grenade literature classifies fragmentation as "HE." Most designs contain 1oz to 3oz (28gr to 85gr) of high explosives housed in a serrated or micro-engraved metal body designed to fragment upon impact (Figures 6.25 through 6.27).

General identification features include:

Materials and Appearance:

- Color codes that deviate from common standards.
- 25mm to 40mm in diameter.
- Rotating band or gas-check bands.
- Aluminum nose fuze housing or rounded aluminum ogive covering the fuze.
- An internally serrated smooth body, or a "ribbed" external appearance on the base.

Figure 6.27 Left to right: German 40mm, DM112 HEDP. Center: German 40mm, DM111 HE-PFF (Pre-Formed Fragments). (Courtesy of Didzis Jurcins.)

Markings: Color codes are a departure from most standards, including anodized gold-colored ogives, with gold, green, black, or yellow body colors; with black, yellow, or white markings. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: PD fuzing is common. VT fuzing is uncommon, but available. Some designs incorporate a self-destruct (S/D) feature.

General Safety Precautions:

- HE, frag, movement.
- Safety precautions for fuze, if present.

3.b. Category: Projected Grenade. Group: Bounding HE-Fragmentation: Obsolete designs that are slightly longer than HE-frag models. Upon impact, an ejection charge bounds a fragmentation ball approximately 3ft (1m) before functioning. Most designs contain 1oz to 3oz (28gr to 85gr) of high explosives housed in a serrated or micro-engraved metal body designed to fragment upon impact.

General identification features include:

Materials and Appearance:

- Color codes that deviate from common standards.
- 25mm to 40mm in diameter.
- Rotating band or gas-check bands.

- Aluminum nose fuze housing or rounded aluminum ogive covering the fuze.
- The base offers the key difference between a HE-frag, a bounding HE-frag, and a HEDP. A bounding HE-frag has an internally serrated smooth body, or a "ribbed" external appearance that is counter-sunk into the base and crimped in place.

Markings: Color codes are a departure from most standards, including anodized gold-colored ogives, with gold, green, black, or yellow body colors; with black, yellow, or white markings. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: PD fuzing is common. VT fuzing is uncommon, but available. Some designs incorporate a self-destruct (S/D) feature.

General Safety Precautions:

- HE, frag, movement.
- Safety precautions for fuze, if present.

3.c. Category: Projected Grenade. Group: HEDP (High Explosive Dual Purpose): The United States and other countries moved away from the single-purpose HE projected grenades in favor of a HEAT configuration housed in a serrated or micro-engraved metal body designed to penetrate armor and fragment like an HE grenade. For projected grenades, this configuration is defined as High Explosive Dual Purpose (HEDP) or anti-tank/anti-personnel (AT/AP) as seen in Figures 6.24 and 6.27. With the exception of identifiable markings and perhaps the length of the body, it is usually difficult to distinguish a HE from an HEDP projected grenade.

General identification features include:

Materials and Appearance:

- Color codes that deviate from common standards.
- 25mm to 40mm in diameter.
- Rotating band or gas-check bands.
- Aluminum nose fuze housing or rounded aluminum ogive covering the fuze.
- An internally serrated smooth body, or a "ribbed" external appearance.

Markings: Color codes are a departure from most standards, including anodized gold-colored ogives, with gold, green, black, or yellow body colors; with black, yellow, or white markings. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: BD or PIBD-spitback fuzing is common. Some designs incorporate a self-destruct (S/D) feature.

General Safety Precautions:

- HE, frag, movement, jet.
- Safety precautions for fuze, if present.

3.d. Category: Projected Grenade. Group: Burning Smoke, and Riot Control: Contain pyrotechnic mixtures that burn to produce colored smoke for signaling and screening. A small flame and hot gas are produced with the colored smoke, but the grenade body remains intact after functioning. The only difference between colored smoke and riot control projected grenades are the CN, CS, CN1, or other pepper-like riot control substances used in the latter.

Most riot control projected grenades are deployed by law enforcement in 37mm and 38mm rather than more common military standard diameters. Due to the similarity of designs, riot-control projected grenades will be covered with burning smoke (Figure 6.28).

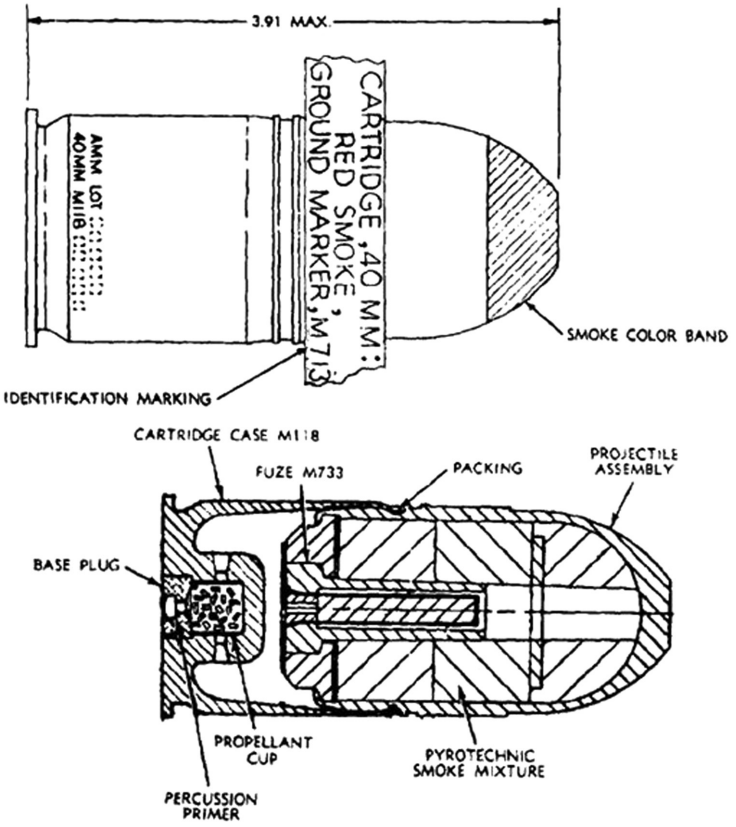


Figure 6.28 U.S. 40mm, M713 Burning Smoke. (From U.S. Military TM.)

General identification features include:

Materials and Appearance:
- Color codes that may deviate from common standards.
- 25mm to 40mm in diameter.
- Rotating band or gas-check bands.
- Telltale emission hole or holes in the base.
- Possible rubber or plastic body for riot-control versions.

Markings:
- A lime green or gray body with yellow and red markings are common.
- Riot-control may have gray or unpainted silver body with red bands or markings.
- The ogive color or a band on the body may indicate the color smoke produced.
- Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: Base fuze with a pyrotechnic delay that is ignited upon firing is common.

General Safety Precautions:
- Movement, fire.
- Chemical for burning riot control.
- Safety precautions for fuze, if present.

3.e. Category: Projected Grenade. Group: Illumination: A dispenser that ejects a parachute-suspended, pyrotechnic candle to illuminate an area at night. After firing, a time fuze functions at a preset time, initiating a low-explosive expelling charge. The pressure generated overcomes the pressed or threaded nose, ejecting the payload. The illumination candle may be ignited during ejection, or upon parachute deployment via a separate fuzing system (Figure 6.29). There are also star-cluster designs for signaling that do not have a parachute but provide substantial illumination while falling quickly to the ground.

General identification features include:

Materials and Appearance:
- Aluminum or plastic-coated paper with smooth outer appearance.
- An internal fuze.
- Plastic ogive that looks like a cap.

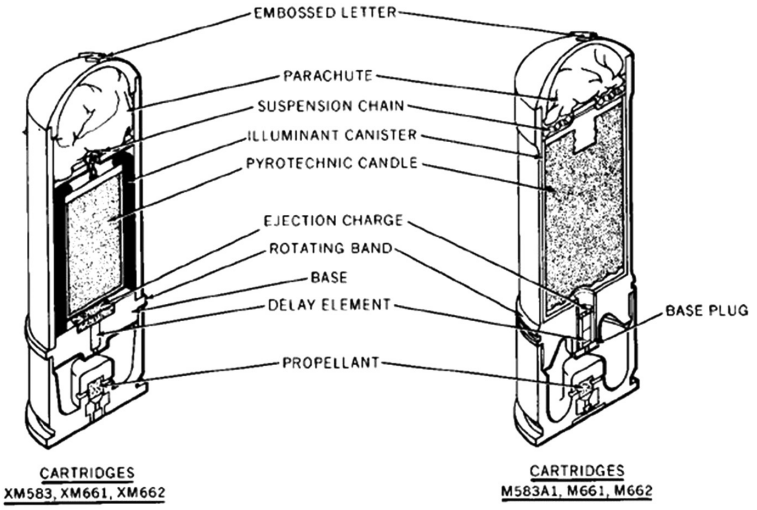


Figure 6.29 Internal configurations of two U.S. 40mm illumination candles with parachutes. (From U.S. Military TM.)

Markings:

- A white body with black markings is common.
- Some designs have specific markings. For example, U.S. 40mm illumination projected grenades with parachutes have a slightly dome-shaped ogive embossed with a letter to identify the payload, W = white, G = green, and R = red (Figure 6.30).
- On the ogive of star cluster projected grenades there are also five raised dots around the outer edge.
- The umbrella-like symbol seen in Chapter 4, Figure 4.28.
- Other colors and stamped or stenciled markings, and symbols, may also be present.

Common Fuze Configurations: PTTF fuzing to deploy the payload. Candle may be ignited by the ejection charge, or during parachute deployment via a mechanical pull-initiated fuze.

General Safety Precautions:

- Movement, ejection, fire.
- Chemical if burning as smoke is toxic.
- Do not look directly at a burning candle.
- Safety precautions for fuze, if present.

3.f. Category: Projected Grenade. Group: Practice: Designed to fire with the same ballistic characteristics as the live projected grenade it mimics,

Figure 6.30 The ogive with raised "W" designating a white-illumination candle. (Author's photograph.)

minus the destructive effects. Practice models may be solid metal, contain an inert filler such as gypsum and wax to simulate explosives weight, or powdered dye that bursts to leave a large mark when impacting a target. Other designs contain a live fuze with an explosive charge to propel chlorosulphonic acid (FS) or other spotting materials to the point of impact. With deployment ranges exceeding 2km, some practice projected grenades contain substantial spotting charges.

There are four common configurations of practice projected grenades:

1. Solid one-piece metal construction (Figure 6.31, right).
2. A live fuze with an explosive that expels a spotting charge strong enough to blow open the steel base (Figure 6.31, left).
3. Thin plastic body containing a marking dye that bursts upon impact.
4. A live fuze with smoke pellets in the body that are disbursed upon impact.

Figure 6.31 Left: U.S. 40mm M918 with an aluminum ogive, steel body, and copper rotating band. Note the curled steel base where the spotting charge was explosively ejected. Right: U.S. 40mm M385 practice, solid aluminum with copper rotating band. Note the propellant charge burned into the base, which will not happen on the steel-based M918 or an HEDP munition (Author's photograph.)

General identification features include:

Materials and Appearance:

- Construction features consistent with the projectile they are designed to imitate.
- Plastic body for dye-filled designs.
- Easily mistaken for toys or paintball munitions.

Markings: A blue body with or without brown markings and a brown band are common. However, black bodies with white markings, yellow bodies with black markings, and other color combinations are also common.

Common Fuze Configurations: PD fuzing.

General Safety Precautions:

- Movement.
- Observe all applicable safety precautions for the live grenade until positive identification is made.
- HE, frag, ejection when a spotting charge is present.
- Safety precautions for fuze, if present.
- Practice means practice, it does not mean inert.

Closing

Grenades are the most commonly encountered ordnance items outside military control. Hand, rifle, and projected grenades are inherently dangerous. Until proven otherwise, always consider a grenade to be in a hazardous condition.

If unable to identify a grenade that appears old, applying the information on older munitions from Chapter 13 may help.

Ordnance Category—Guided Missiles

7

Victory smiles upon those who anticipate changes in the character of war, not upon those who wait to adapt themselves after they occur.

General Guilo Douhet (Italian), 1921

Introduction

While General Douhet's comments 100 years ago referred primarily to chemical and aerial warfare, they still apply to the advanced guidance systems of today's highly sophisticated Guided Missile (GM) systems. The history of GM development is an offshoot of rockets. Today's guided missile is a rocket system enhanced with a guidance section or brain capable of target selection and steerable surfaces providing an ability to change trajectory during flight. As such, all the information concerning propellants, rocket motors, and venturis covered in previous chapters, also applies to missiles. Of course, the motors used on missiles are referred to as "missile motors" versus rocket motors.

For this chapter, the defining factors categorizing a munition as a "Guided Missile" are:

1. The munition is propelled by a missile motor or motors as its primary means of deployment.
2. The munition is internally or externally guided and capable of altering its trajectory while in flight.

These defining factors are easy to recognize if the motor remains attached to the warhead, which is not always the case. See Appendices D and E for information on marking schemes.

Missile Types

There are four types of missiles covered. Some designs can be fired from both ground and air platforms, but most are configured for one, making this a "Type" characteristic and helpful for identifying an unknown missile. Missile types are:

1. **Surface-to-Surface Missiles:** Are fired from the ground or water by infantrymen, vehicles, unmanned mounts, and ships; against targets that are also on the surface.
2. **Surface-to-Air Missiles:** Are fired from the ground or water by infantrymen, vehicles, unmanned mounts, and ships; against airborne targets, including fixed-wing aircraft, helicopters, unmanned drones, rockets, or other missiles.
3. **Air-to-Surface Missiles:** Are fired from aircraft, both fixed-wing aircraft, helicopters, and unmanned drones; against ground or water-based targets.
4. **Air-to-Air Missiles:** Are fired from aircraft, both fixed-wing aircraft, helicopters, and unmanned drones; against other airborne targets, including fixed-wing aircraft, helicopters, unmanned drones, rockets, or other missiles.

Key Identification Features

If the missile type can be ascertained, the number of possibilities will be cut by approximately 75%, making the identification process more expedient.

Guided Missiles are expensive items, usually manufactured to higher standards than other ordnance categories. Missiles incorporate quality materials such as lightweight, yet durable aluminum and titanium parts, thermal power sources, complex electronics, and utmost craftsmanship are good indicators of a guided missile, or missile components.

There are exceptions to every rule and some missiles are guided by means other than steerable fins. For example, after launch, the U.S. M47 Dragon AT, GM is propelled and steered by 66 small, side-mounted motors.

When inspecting an unknown munition that could be a guided missile, focus on these two areas:

1. The location and number of motors: These will provide key identification features and address mid-body venturis posing an angle of approach hazard, addressed in Step 1.
2. How the missile is guided: Provides key identification features, and also addresses safety concerns about the orientation of fuze sensing elements, and the presence of heavy metals.

Guided Missile Sections and Defining Features

Guided missiles are composed of multiple components, and while the definitions provided for nose, ogive, bourrelet, and base still apply, the following components are also prevalent and important.

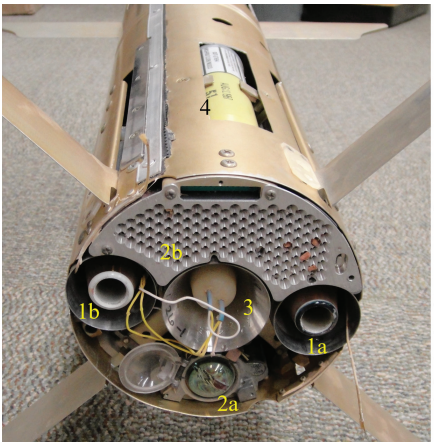
Guidance Section: Early guidance systems were external to the missile and some still are, but technological advancements allowed them to be part of the missile itself. There are many ways in which a missile can be guided, including by TV, laser, radar, infrared, and wire. Depending on design, guidance sections can be located in the front, rear, or toward the middle of a missile (Figures 7.1 and 7.2). Depending on the technology used, guidance may or may not involve the person firing the missile having to continuously guide it until reaching the target. If not continuously guided, the term "fire and forget" is used to describe missiles capable of following predetermined routes, or differentiating between targets and, in many cases, selecting which target to go after. Examples include:

Wire Guided: A person controls the missile by providing flight path changes transmitted through wire that unspools throughout the missile's flight (Figure 7.1).

Target Designator: A person selects a target and uses a designator to "show" the missile. A common configuration is for a person to show the target, then fire the missile. After firing, the missile has everything required to engage the target and differentiate between the target and countermeasures deployed to appear like more valid target options (Figure 7.2), a capability referred to as "fire and forget." The ability for a missile to see a target and differentiate between multiple targets and countermeasures is an important safety consideration, addressed under the VT safety precaution.

Terrain Mapping: Key terrain features seen by the missile during flight are compared to a programmed flight path. Course corrections are made to keep the missile on track until it reaches the target.

Control Section: Consists of the electrical and mechanical components that take information from the guidance section and convert it into



TOW-2A HEAT:
1a: Guide wire
1b: Guide wire
2a: Guidance
2b: Guidance
3: Motor venturi
4: High pressure bottle

Figure 7.1 U.S. TOW-2A, base configuration for wire guidance. (Author's photograph.)

Figure 7.2 Damaged seeker on Russian SA-16 in the launch tube. (Author's photograph.)

adjustments to movable portions of fins to alter the missile's flight path (Figures 7.3 and 7.4).

Fin Assemblies: Missiles usually have more than one set of fins, with one fixed and a second that is movable or has movable sections. Fins can also pose an ejection hazard as some open with tremendous force. Some deigns incorporate fin deployment into the arming process by completing circuits when fully opened. If present, fins offer a differentiating feature between a missile and a rocket. Many missile systems will have multiple versions of the same missile and a specific fin design may be the only external means of telling them apart.

Motor Section: Some large missiles are propelled by a jet engine. The missile motors discussed here include designs similar to rocket motors and consist of a body, igniter, propellant, and one or more venturis. Many missile designs contain more than one motor, in which case a common configuration is a "launch" motor to initially deploy the missile, and a "flight" motor to allow the munition to travel to the intended target. Examples of this two-motor configuration include the U.S. Stinger, Russian SA-16 (Figures 7.4 and 7.5), and the U.S. TOW (Tube-launched, Optically-tracked, Wire-guided) missile (Figures 7.1, 7.8, and 7.9).

Figure 7.3 Steerable fins mounted on the control section of a U.S. High Speed Anti-Radiation Missile (HARM). (Author's photograph.)

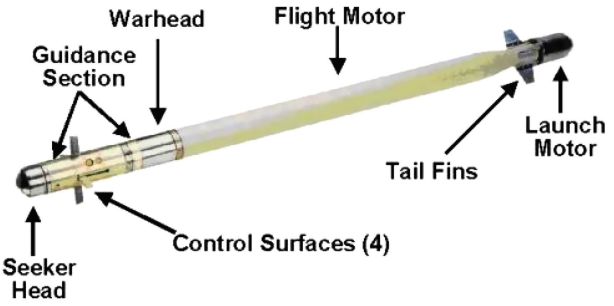


Figure 7.4 U.S. Stinger, Surface-to-Air missile. Note: After initial deployment, the launch motor falls away allowing unobstructed functioning of the flight motor. (From U.S. Military TM.)

Warhead Section: The warhead defines the group to which a missile belongs. Internally, missile warheads share many characteristics with rockets; however, due to the way missiles are constructed, these identifiable characteristics may be masked by ballistic shields or other components. Additionally, due to the speeds involved, a missile may break-apart upon

Figure 7.5 Launch motors from a Russian SA-16 Surface-to-Air missile. Unfired on the left, and fired on the right. SA-16 and Stinger motors are configured the same way (Figure 7.4) and this motor will fall away after firing. (Author's photograph.)

impact. When a warhead is found separated from the missile body, apply all safety precautions associated with the missile it is suspected to be as the fuze may still be attached (Figure 7.6).

Fuze Section, Safe and Arming Device (S&A): Are complex, multi-option fuzes with the ability to discriminate between targets and may be completely

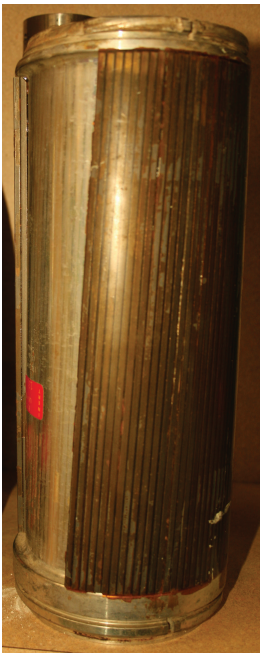


Figure 7.6 Continuous Rod Warhead (CROW) from U.S Sidewinder Air-to-Air missile. (Author's photograph.)

internal, thus offering few clues to their existence. As with all ordnance categories and groups, missile fuzing is usually designed to require three or more actions to arm, which coincide with the means of deployment.

Missile fuzing configurations are usually more complex to compensate for the way they are deployed or the speeds involved. For example, an anti-aircraft missile traveling over Mach 2, closing on an aircraft traveling toward it at Mach 1 has a closing speed exceeding 2,000 mph (3,220 kph) and three functioning options:

1. Impact the target and function.
2. If the targeted aircraft successfully initiates flight changes to counter or avoid impact; the missile will switch to VT-Proximity-mode to function the warhead as close to the target as possible and hopefully inflict lethal damage.
3. When options 1 and 2 fail, many S&A devices contain a self-destruct feature to destroy the missile.

   For example, anti-aircraft munitions that fail to impact a target incorporate a self-destruct S/D feature to ensure an intact munition does not fall to the ground and detonate. By self-destructing, the missile will fall to the ground in small pieces less likely to cause death or injury.

The Seven-Step Practical Process and Guided Missiles

Examples of different designs, color codes, markings, and construction features are provided throughout this chapter.

Step 1: Gather Information, Approach, and Initial Inspection: Attempt to identify from a safe distance with binoculars. If no mid-body motor is present, approach at a 45° angle from the rear to avoid venturis and fuze sensing elements; if present, approach at a 90° angle to avoid venturis. If a mid-body motor is present, the missile is most likely wire-guided, making a 90° angle approach more feasible.

With sketch pad and camera, document identifying features including fins, venturis, materials used, means of attaching the warhead to the motor, leaking material, color codes, stamped markings, construction features, damage, signs of tampering or modification.

Measurements must be taken at the widest point of each separate component, in addition to recording overall length. The three fastest means of researching an unknown missile are:

1. The largest diameter and overall length
2. The locations and number of venturis
3. Which fins are movable or have movable surface.

Step 2: Determine Fuze/S&A Group, Type, and Condition:

Some missile systems use the term safe and arm device, or "S&A" versus "fuze" to describe a fuzing system.

If a missile has been fired (step 5), the fuze is considered armed. If the fuze is damaged or alterations have been made, it is considered armed. If visible, measurements for the fuze are taken separately from the munition.

Step 3: Determine Ordnance Category:

The category "guided missile" is covered throughout this chapter.

Step 4: Determine Ordnance Group:

The identifiable characteristics associated with each guided missile group are covered throughout this chapter.

Step 5: Determine if Munition was Deployed:

Inspect the missile for impact-related damage, missing pins, or clips. On the motor, look for blistered paint or heat-related markings indicating the motor has fired. Check venturis for closure disks or plugs; if missing, assume the missile was fired.

Step 6: Determine Safety Precautions:

Safety precautions for each guided missile group are covered in this chapter. Once identified, these precautions must be adhered to.

Warning: The complex design of missiles includes substantial hazards not common with other ordnance categories. Examples include high-pressure gas bottles, generators for hydraulic power, high-voltage thermal batteries, and capacitors; in addition to toxic compounds such as mercury thallium, other heavy metals, and radiological sources used in guidance sections.

Until these hazards are identified or ruled out, consider applying the chemical safety precaution for a damaged missile.

Step 7: Research Literature and Identify the Munition:

Apply the totality of measurements, color codes, stamped markings, and construction features to determine the group, and positively identify the munition and fuzing configuration.

Groups

The guided missile category is divided into the following primary and supplemental groups:

1. HE-Fragmentation
2. HEAT
3. Dispenser
4. Practice
5. Drill

1. Category: Guided Missile. Group: HE-Fragmentation: Designed to explode and destroy targets with blast, fragmentation, and thermal effects. Missile designs within this group differ substantially and are more diverse than those in other groups.

For example, anti-aircraft missiles have HE warheads ranging in size from less than 1lb (.4kg) of explosives, such as a man Portable Air Defense System (MANPADS) (Figures 7.2 and 7.4) to barrel-size warheads containing hundreds of pounds of HE such as the truck-launched SA-2 (Figure 7.7). MANPADS are designed to destroy small, low-flying aircraft, while large truck-launched Surface-to-Air Missiles (SAMs) are designed to destroy large bombers flying over 40,000ft (12,192 meters); however, they both share a common characteristic. Anti-aircraft munitions are usually designed to function upon impact with a target; however, if the missile is going to miss and function in proximity-mode, the intent is to saturate the airspace with fragmentation and inflict as much damage as possible. As the latter option is likely, HE-frag warhead designs often involve multiple layers of unique fragmentation sleeves or liners, such as the CROW in Figure 7.6. Upon detonation, multiple layers of approximately 1ft long (305mm), square-shaped rods are explosively projected outward like spinning buzz saws.

Another example is an anti-ship missile designed to function after penetrating the side or deck of a ship incorporating warheads with anti-deflection features. If the missile impacts the ship at an angle and is unable to penetrate, this feature will ensure the warhead is not deflected and functions as closely to the target as possible.

Figure 7.7 The author inspecting damaged SA-2 missile in Kuwait, 1st Gulf War. (Author's photograph.)

General identification features include:

Materials and Appearance:

- Multi-piece construction.
- Made with high quality materials and machining.
- Fin configurations with movable surfaces.
- A motor on the aft end, and possibly a second mid-body.
- One or more venturis on the base or side of the body.
- A nose-cone or cap made of glass or plastic.
- Guidance components, wire spools, or glass on the base.

Markings: White, gray, green, and black bodies with yellow, white, or black markings are common. A brown band may be present on the motor. Warhead and motor colors may match or be completely different. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze, S&A Configurations: Electrical impact, VT, and self-destruct (S/D) fuzing is common. Some anti-aircraft VT configurations include side-mounted proximity sensors working in sync with nose-mounted sensors. S&A devices are usually not observable and may not have markings.

General Safety Precautions:

- HE, frag, movement for the warhead and motor.
- Ejection, EMR, static for an unfired motor.
- Chemical, if guidance section or motor is damaged or leaking.
- Safety precautions for fuze, if present.

2. Category: Guided Missile. Group: HEAT: Contain a shaped charge warhead to defeat armored and other hardened targets. Figures 7.8 and 7.9

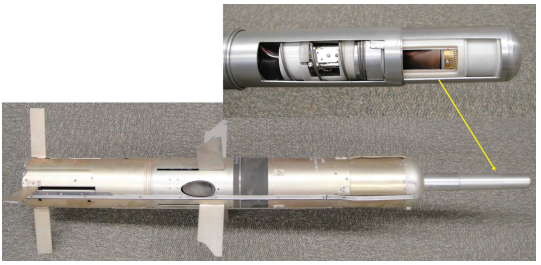


Figure 7.8 U.S. TOW-2A, HEAT missile. The standoff spike houses a small shaped-charge to initiate reactive armor, while stressing the PE crystal for the main warhead. Note the wires running below the white plastic component. (Author's photograph.)

Figure 7.9 The family of U.S. TOW missiles. Left to right: The TOW, Improved TOW or "ITOW, TOW-2, TOW-2A, and laying in front, the TOW-2B with downward firing warhead. (From U.S. Military TM.)

provide insight on the development of the U.S. TOW missile to circumvent countermeasures. Figure 7.10 is a similar and very effective French Milan design.

General identification features include:

Materials and Appearance:

- Multi-piece construction.
- Made with high-quality materials and machining.
- A break in the major diameter, behind the ogive.
- A hollow ogive, riveted or screwed to the body.
- Fin configurations with movable surfaces.
- A motor on the aft end, and possibly a second mid-body.
- One or more venturis on the base or side of the body.
- A nose-cone or cap made of glass or plastic.
- Guidance components, wire spools, or glass on the base.

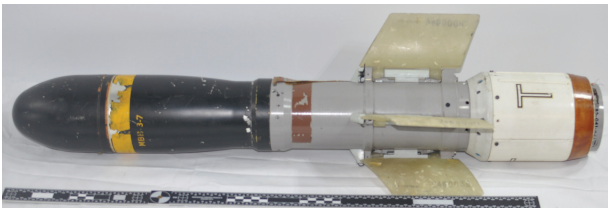


Figure 7.10 French, Milan HEAT missile. (Courtesy of Dan Evers.)

Markings: Green, white, and gray bodies with yellow or black markings are common. A brown band may be present on the motor. Warhead and motor colors may match or be completely different. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: Electrical PIBD or BD with S/D fuze:

General Safety Precautions:

- HE, frag, movement, jet for the warhead and motor.
- Ejection, EMR, static for an unfired motor.
- Chemical, if guidance section or motor is damaged or leaking.
- Safety precautions for fuze, if present.

3. Category: Guided Missile. Group: Dispenser: A hollow warhead with a payload sealed inside. The term "dispenser" is reserved for warheads containing HE or HEAT submunitions.

After firing, an electronic time fuze functions at a predetermined time to release springs or initiate a low-explosive expelling charge to eject the payload. With a missile motor fixed to the base, most missile dispensers open like clam-shells to deploy payloads.

General identification features include:

Materials and Appearance:

- Multi-piece construction. May see seams on side of warhead.
- Made with high quality materials and machining.
- Fin configurations with movable surfaces.
- A motor on the aft end, and possibly a second mid-body.
- One or more venturis on the base or side of the body.
- Nose-cone made of glass or plastic.
- Guidance components, wire spools, or glass on the base.

Markings: The payload may define the color codes and markings. If not, then green, white, and gray bodies with yellow or black markings are common. A brown band may be present on the motor. Warhead

and motor colors may match or be completely different. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: ET fuzing, which may include an S/D feature.

General Safety Precautions:

- Movement, ejection for the warhead.
- HE, frag, EMR, static, ejection for unfired motor.
- Depending on the payload, HE, frag, jet may apply.
- Chemical, if guidance section or motor is damaged or leaking.
- Explosively deployed payload offers substantial ejection hazard.
- Safety precautions for fuze, if present.

4. Category: Guided Missile. Group: Practice: Due to the excessive expense associated with guided missiles, few practice missiles are designed to be fired. In order to address training needs, many practice missiles are fitted with active guidance systems and tracking software allowing a gunner to simulate firing the missile and have the accuracy of the "shot" tracked by computer software. Though a live warhead or motor is not present, many missiles still possess substantial hazards.

General identification features include:

Materials and Appearance:

- Construction features consistent with the rocket they are designed to imitate.
- Electrical connections on the body, inconsistent with conventional design.
- Fully functioning guidance section.

Markings: A blue, gray, or yellow body with white or black markings are common. A lack of yellow or brown bands. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: None.

General Safety Precautions:

- Movement.
- Observe all applicable safety precautions for the live guided missile until positive identification is made.
- Chemical, if guidance section is damaged or leaking.
- Practice means practice, it does not mean inert.

5. Category: Guided Missile. Group: Drill: Incapable of firing, these missiles are designed to be used for weapon system loading and unloading drills, display, or training and contain no energetic materials whatsoever.

General identification features include:

Materials and Appearance:

- Construction features generally consistent with the guided missile they are designed to imitate.

Markings: Gold, black, gray, or blue bodies with white markings are common. A lack of yellow or brown bands. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: None.

General Safety Precautions:

- Movement.
- Observe all applicable safety precautions for the live guided missile until positive identification is made.

Closing

All ordnance, including practice missiles are inherently dangerous. Until proven otherwise, always consider a guided missile to be in a hazardous condition and remember the additional threats associated with mercury thallium and other toxic materials commonly used with missile guidance systems.

Ordnance Categories—Aerial Bombs and Dispensers

8

Viewed from half a world away, a bomb is a political concern; viewed from less than a foot away, a bomb is just a high-stakes exercise in problem solving, where making a mistake means a final, terminal education in the physics of expanding gases.

The Hurt Locker, 2008

Introduction: Aerial Bombs

The quote from *The Hurt Locker* referenced Improvised Explosive Devices (IEDs) but is also applicable to conventional ordnance. The largest nonnuclear bomb manufactured by the United States was the T-12 "Cloudmaker," weighing 43,600lb (19,800kg) and classified as an "Earthquake bomb." The largest bomb in current U.S. inventory is the GBU-43/B Massive Ordnance Airblast Bomb (MOAB) weighing 21,000lb (9,525kg).

The overall focus of this book is on the smaller ordnance items more commonly encountered outside military control. While the theft or loss of a bomb weighing 500lb (227kg) does occasionally occur, most often when a bomb is discovered outside military control, its fundamental identity is usually recognized. As such, this chapter briefly covers aerial bombs and dispensers, focusing on identifiable characteristics driving safety precautions.

For this chapter, the defining factors that categorize a munition as a "bomb" are a munition:

1. Dropped from an Aircraft: A bomb must be securely attached to an aircraft prior to dropping. The "lugs" or "cleats" used to do this provide excellent identifying features; however, there are two exceptions that must be mentioned:
   a. Early generation aerial bombs were modified projectiles with fins, dropped from the open cockpit of an aircraft.
   b. Large MOAB-type bombs are deployed from large cargo aircraft on a sled that slides out the back. As such, they do not have a means for attaching to an aircraft.

2. Not Covered by Rocket or Missile Definitions: An exception for "smart bombs." The guidance systems affixed to make a bomb smart, provides the ability to alter flight path, which is a defining characteristic of a missile. There are also smart bomb configurations including a motor on the base fin assembly to propel and extend the bomb's delivery range. A motor used for propulsion is a defining characteristic of missiles and rockets, but is an exception also associated with bombs.

Delivery Systems

Bombs can be delivered from any airborne platform from the Zeppelins of WWI, to the rotary and jet aircraft used today. For over 100 years, bombs have been successfully delivered from their primary platform, fixed-wing aircraft, both manned and unmanned.

Key Identification Features

Most bombs consist of a body with a means of attaching to an aircraft and orientating itself in flight. There are exceptions such as extremely large bombs that are deployed via parachutes and others designed to tumble. These specific characteristics help identify to which group a bomb belongs. See Appendices D and E for information on marking schemes.

Bomb Sections and Defining Features

Starting from the tail, or aft end of a bomb, the following definitions apply.

Base: The base and any components affixed to the base are likely to survive impact with minimal damage and provide identifiable information. For example, the U.S. manufactured, MK-80-series bombs have the filler stamped on the base.

Excluding bombs with transverse fuzing (Figure 3.2) in Chapter 3, most bombs have a fuze well in the base.

Fin Assemblies: There are bomb designs without fins that will be covered later in this chapter. However, most bomb designs include fins that fall into two categories, high and low drag:

- **High-Drag Fins:** Also called "Retardation Devices" are designed to rapidly decelerate a bomb after deployment and maintain stable flight as it descends. The tactical application is to allow fast moving aircraft to deliver bombs at low levels without being damaged by the bombs they drop. Examples of high-drag fins include parachutes housed in large, square-shaped fin assemblies (Figures 8.1 and 8.2)

and "Snakeye" fins (Figure 8.3). The violent opening shock of the parachute or Snakeye fin can be incorporated into the arming sequence for bomb fuzes designed to be deployed for this tactical purpose.

- **Low-Drag Fins:** Aerodynamically orient a bomb and offer no additional drag. Designs include the conventional open-conical, four-fin boxed style (Figure 8.4), and multi-fin enclosed configurations (Figure 8.5).

Attachment to Aircraft: Excluding bombs dropped from an open cockpit or off the ramp of large cargo aircraft, lugs, or "cleats" are the most common means of attaching a bomb to an aircraft. Most aircraft employ a two-lug configuration, but some use a single lug. Bombs that can be dropped from various aircraft types often have two lugs on the body with a single lug 180° from the other two lugs (Figures 8.4 and 8.5).

If a bomb were simply dropped, the aerodynamics of many aircraft would cause the bomb to repeatedly strike and damage the aircraft. In order to negate this possibility, a "crow's foot" powered by an explosive cartridge housed in the pylon ejecting the bomb is positioned in contact with it, between the lugs. When the bomb is released, the crow's foot is explosively thrust outward forcing the bomb away from the aircraft.

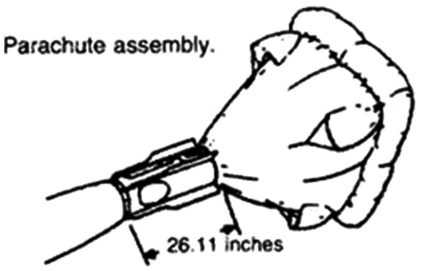


Figure 8.1 U.S. Parachute retardation fin assembly. (From U.S. Military TM.)

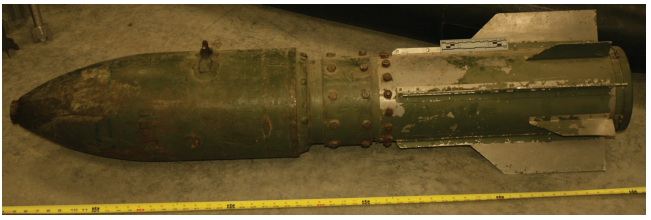


Figure 8.2 Egyptian 100kg (220lb) GP bomb with single welded lug and a parachute retardation fin assembly. (Author's photograph.)

Figure 8.3 U.S. Snakeye retardation fin assembly on MK-82, 500lb (226kg) bomb. Green body with unconventional white marking designates an inert filler. (Author's photograph.)

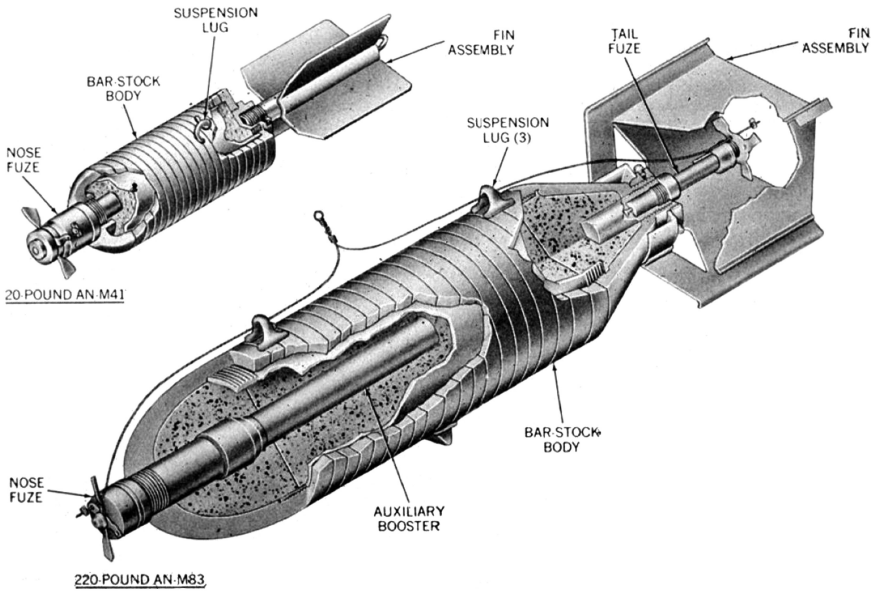


Figure 8.4 Low drag fin designs. Bottom: high-drag general purpose (GP) bomb with additional fragmentation. (From U.S. Military TM.)

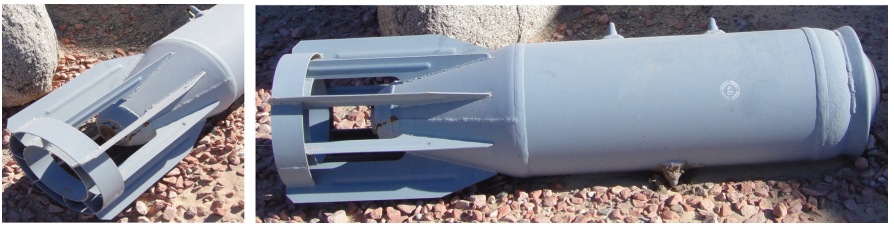


Figure 8.5 "Captured" fin design, associated with bombs from China, Russia, and Eastern Europe. (Author's photograph.)

Fuze: Many bomb fuzes require three actions to arm that coincide with deployment characteristics, such as high or low drag fins. Electrical fuzes may have arming wires pulled and receive a surge of power from the aircraft as the bomb is released from the aircraft; or after release, some fuzes have an on-board wind generator that may spin, providing power as the bomb falls. Mechanical fuzes may have arming wires pulled as the bomb is jettisoned from the aircraft, freeing other components to move and arm the fuze as the bomb falls.

If a nose or tail fuze is sheared off flush by impact, components required to function the fuze may still be present inside the bomb. If a nose or base fuze can be seen, the wrench flats, spanner holes or slots, and the overall construction will provide relevant information to its identity. Additionally, the presence of a fuze adapter or booster adapter between the fuze and bomb may help identify both the fuze and the bomb.

The Seven-Step Practical Process Applied to Bombs

Examples of different designs, features, color codes, markings, and construction features are provided throughout this section.

Step 1: Gather Information, Approach, and Initial Inspection: Attempt to identify from a safe distance with binoculars. Approach at a 45° angle from the rear, avoiding fuze sensing elements and the opening arc of fins.

With sketch pad and camera, document identifying features including fins, number of lugs, venturis, leaking material, color codes, stamped markings, construction features, damage, signs of tampering or modification. Look for stamped data, focusing on the area between the lugs and on the base. Note the texture of the body as smooth or rough with a "gator-skin-like" coating.

The three fastest means of researching an unknown bomb are:

1. The diameter at mid-body
2. The overall length and distance between lugs
3. The method of orientation, type of fin assembly

Step 2: Determine Fuze Group, Type, and Condition: If a bomb has been deployed (step 5), the fuze is considered armed. If the fuze is damaged, pins have been removed, or alterations have been made, it is considered armed. If visible, measurements for the fuze are taken separately from the munition.

Step 3: Determine Ordnance Category:

The category "bomb" is covered throughout this section.

Step 4: Determine Ordnance Group:

The identifiable characteristics associated with each bomb group are covered throughout this section.

Step 5: Determine if Munition was Deployed:

Inspect for impact-related damage, missing pins, or clips.

Step 6: Determine Safety Precautions:

Safety precautions for each bomb group are covered in this chapter. Once identified, these precautions must be adhered to.

Step 7: Research Literature and Identify the Munition:

Apply the totality of measurements, color codes, stamped markings, and construction features to determine the group, and positively identify the munition and fuzing configuration.

Groups

In order to provide a congruent flow, the bomb category is divided into the following primary and supplemental groups:

1. High Explosive
   a. Fragmentation
   b. General Purpose (GP) High Drag
   c. GP Low Drag
   d. Demolition
   e. Penetration
   f. Guided
2. Fuel Air Explosive (FAE)
3. Fire:
   a. Photoflash
   b. White Phosphorus (WP)
   c. Napalm
   d. Incendiary
4. Practice:
   a. With explosives or spotting charges
   b. Inert

1. Category: Bomb. Group: HE: Designed to explode and destroy targets with blast, fragmentation, and thermal effects. However, penetration bombs

detonate well below the surface, thus negating fragmentation effects (1e). Explosive fillers range from a few pounds to hundreds of pounds and may be solid, pliable, or in liquid form.

Six of the seven HE bomb types are closely related. Only FAE bombs (1 g) function in a significantly different way. Examples provided in this section do not include bomb types with transverse fuzing seen in Figure 3.2, in Chapter 3, "Fuze Functioning."

1.a. Category: Bomb. Group: Fragmentation: Consists of high explosives housed in a metal body with additional internal or external fragmentation. Figure 8.4 provides two examples. Lugs are usually welded to the body.

1.b. Category: Bomb. Group: GP High Drag: Contain high explosives housed in a metal body. Figures 8.1 and 8.3 show U.S. GP high drag bomb body configurations, with the addition of an external fragmentation sleeve. Most U.S. high drag designs are for aircraft with internal bomb bays. Lugs are usually welded to the body. Note the high-drag shape of these bombs, which are often referred to as "old-style."

1.c. Category: Bomb. Group: GP Low Drag: Configurated with a sleek low-drag shape with internal electrical plumbing between fuze-wells allowing electric fuzing to communicate (Figure 3.1, Chapter 3). Lugs are threaded into the body and can be removed to roll the bomb.

1.d. Category: Bomb. Group: Demolition: Consist of high explosives housed in a metal body, with internal electrical plumbing. The designation of "demolition bomb" applies when the explosives weight is 60% to 70% of the overall weight of the bomb (Figures 8.6).

Side-wall of the bomb body is much thinner than GP designs as the primary objective is to produce greater blast effects than GP bombs. Lugs are threaded into the body and can be removed to roll the bomb.

1.e. Category: Bomb. Group: Penetration: A sleek design with a hardened steel body with a hardened-pointed nose. Due to the thickness of the side-walls

Figure 8.6 U.S. M117, 750lb (340kg) demolition bomb recovered by the Cambodian Mine Action Center (CMAC). (Author's photograph.)

and reinforced forward end, explosives weight is much less than other general-purpose configurations. From a targeting perspective, penetration bombs are designed to use the kinetic energy generated during descent to penetrate deeply into the ground or pierce hardened targets prior to functioning.

The resulting blast effects are capable of destroying or collapsing underground facilities and infrastructure. The thick body design of Penetration bombs produces significant fragmentation; however, since they are designed to function subsurface, fragmentation production is not a requirement associated with penetration bombs.

Penetration bombs are often fitted with guidance systems to increase accuracy. Lugs are usually threaded into the body and can be removed to roll the bomb.

1.f. Category: Bomb. Group: Guided: Consist of a GP low drag or penetration bomb fitted with a guidance section and steerable fins. The guidance section has the ability to manipulate the fins so as to steer the bomb toward the target. Older U.S. designed, guided bomb units (GBU) were replaced by the joint direct attack munition (JDAM). With satellite guidance, a 2,000lb (907.2kg) bomb fitted with JDAM guidance is accurate to within 10ft (3m) of the target. During Operation Desert Storm, laser-guided bombs accounted for barely 5% of the bombs dropped while accounting for almost 50% of the targets destroyed.

General identification features for the high explosive bombs covered in 1.a. through 1.f. include:

Materials and Appearance:

- Heavy duty one-piece body construction.
- Fuze adapters are used with many fuze designs.
- Fins or other means of orientation.
- Means of fixing to an aircraft.
- Front, rear, or transverse fuze wells.

Markings: Green, gray, brown, or black body with yellow, red, or black markings are common. Stamped or stenciled markings, and data plates are most likely found between the lugs and on the tail/base. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: PD, BD, PIBD, MT, Chemical long delay, VT, pressure, and influence fuzing configurations are all used with high explosive filled bombs. Fuzing can be located in the nose, tail, or side.

General Safety Precautions:

- HE, frag, movement.
- EMR, Static for guidance systems.

- Ejection for undeployed fins.
- Safety precautions for the fuze if present.

2. Category: Bomb. Group: HE, Fuel Air Explosive (FAE): Are substantially different from more conventional designs, incorporating a high-explosive burster housed in a very thin bomb body filled with a fuel-rich material. Upon functioning, the body fragments as the burster aerosolizes the dense fuel filler and deploys cloud detonators. As the aerosolized fuel mixes with air, a stoichiometric ratio is reached and the cloud detonators function, resulting in an explosion with extremely strong blast effects. The metal body may be prestressed to fragment easily into large, thin pieces that do not travel far.

Additional information on FAE munitions is provided in Chapter 9, Group 1.c. and Figure 9.4.

General identification features for FAE bombs include:

Materials and Appearance:

- Light, one-piece aluminum body.
- Extended fuze for above-ground burst.
- Parachute or fins for orientation.
- Means of fixing to an aircraft.

Markings: Red or a variety of colors. May have chemical markings for filler and high-explosive markings for bursters. Stamped or stenciled markings, and data plates are most likely found between the lugs or base.

Common Fuze Configurations: Impact fuzing. FAE bombs must function very close to the ground making VT and time fuzing impractical. A common configuration is an impact fuze set on an extension that will impact the ground when the body of the munition is 3 or 4ft (1m) off the ground.

General Safety Precautions:

- HE, frag, movement.
- If leaking, Fire and Chemical for toxic filler.
- Safety precautions for the fuze if present.

3. Category: Bomb. Group: Fire:

Although the fuel sources and temperatures vary, all three bomb designs covered under this group produce fire to accomplish the intended goal.

3.a. Category: Bomb. Group: Photoflash: Contain a photoflash mixture to produce an intense flash of light and extremely high temperatures. The U.S. deployed these bombs with time fuzes to function above the ground.

Capable of producing over a billion candlepower, photoflash bombs were dropped as giant flashbulbs for nighttime reconnaissance photography, or as a fire-bomb when set with an impact fuze. Though obsolete, an old photoflash bomb with a deteriorating body offers many hazards.

General identification features include:

Materials and Appearance:

- Thin body of lightweight material.
- Strap-lug configuration (Figure 8.7).
- Older box fin designs are common (Figures 8.4 and 8.7).

Markings: A gray or lime-green body with yellow, red, or black markings are common. Other colors, stamped or stenciled markings, and symbols may be present.

Common Fuze Configurations: MT, PTTF, and PD fuzing.

General Safety Precautions:

- HE, frag, movement, static, fire.
- Chemical if wet. Photoflash powder reacts with water to generate heat and produce hydrogen gas.
- Safety precautions for fuze, if present.

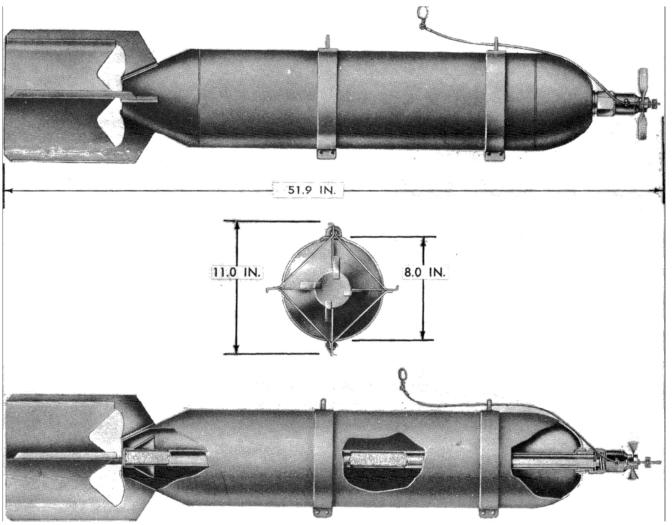


Figure 8.7 U.S. M46 and M47, 100lb (45.4kg) bomb bodies are made of similar design and materials. The thin sheet-steel has a high explosive burster running down the center, two "strapped lugs" as the body is not strong enough to support welded or threaded lugs, and fins. The M46 is a photoflash-filled bomb. Where the M47 fillers include incendiary, chemical, and WP. (From U.S. Military TM.)

3.b. Category: Bomb. Group: White Phosphorus (WP): There are two extremely different designs, both consist of WP sealed in a bomb body. One design is a thin body of lightweight material with a high-explosive burster, such as the one shown in Figure 8.7. The other design, also manufactured by the U.S., named "Crash Pad" consists of a 2,000lb (907.2kg) MK84 with a high explosive burster and three large canisters filled with WP.

When functioned, the burster detonates, breaking the bomb body apart, dispersing the WP.

General identification features include:

Materials and Appearance:
Thin body of lightweight material.
Strap-lug configuration (Figure 8.7).
Older box fin designs are common (Figures 8.4 and 8.7).

Markings: A gray or lime-green body with yellow, red, or black markings are common. Other colors, stamped or stenciled markings, and symbols may be present.

Common Fuze Configurations: PD fuzing.

General Safety Precautions:

- HE, frag, movement, WP, fire.
- Chemical if burning, WP smoke is toxic.
- Safety precautions for fuze, if present.

3.c. Category: Bomb. Group: Napalm: A thickened jelly-like fuel contained in a thin aluminum body or container. The unique aspects that differentiate this from other fire-producing bombs are the design of the body and functioning sequence. A napalm container is designed to be out of balance and is deployed as a fin-less munition to ensure that it tumbles while falling to the ground. Upon impact, the thin body tears open, dispersing napalm as the fuzes function, resulting in a widespread fireball. Threaded lugs and numerous fuze wells in the ends and side are common configurations of napalm-filled fire bombs (Figure 8.8).

General identification features include:

Materials and Appearance:

- Light, one-piece aluminum body.
- Fuze well on each end and side (transverse).
- Lack of fins or other means of orientation.
- Means of fixing to an aircraft.

Markings: Unpainted aluminum body. Stamped or stenciled markings or data plates are most likely found between the lugs. Other colors, stamped or stenciled markings, and symbols may also be present.

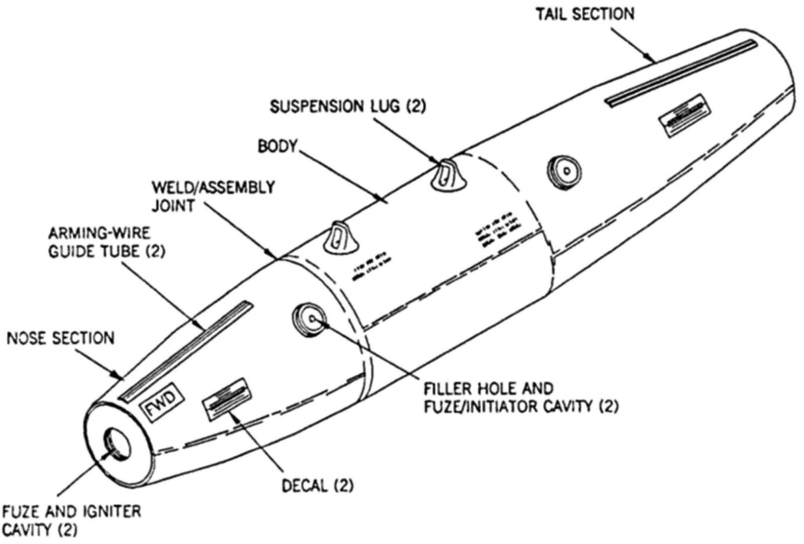


Figure 8.8 U.S. MK77 Firebomb. (From U.S. Military TM.)

Common Fuze Configurations:

- All-Way-Acting. The intended means of deployment requires all-way-acting fuzing.
- Igniters contain WP or Magnesium Teflon (MagTef) and offer significant hazards.

General Safety Precautions:

- HE, frag, movement, fire.
- Safety precautions for fuze and igniter, if present.

3.d. Category: Bomb. Group: Incendiary: There are numerous design possibilities associated with the title "incendiary." For example, the complex list of materials used in the Russian ZAB-500Sh; also known as a "barrel-bomb" (Figure 8.9).

General identification features include:

Materials and Appearance:

- Light, thin-skin metal body.
- Fins, parachute, or other means of orientation.
- Means of fixing to an aircraft.
- Incendiary fillers vary.

Markings: Unpainted aluminum body. Stamped or stenciled markings or data plates are most likely found between the lugs. Other colors, stamped or stenciled markings, and symbols may also be present.

Figure 8.9 Russian 500kg (1,102lb) ZAB-500 SH, barrel-bomb contains: 195kg (430lb) of OM-68 flammable mixture, 5.8kg (12.7lb) gasoline, 9.1kg (20lb) yellow phosphorus, 6kg (13.2lb) high-explosive burster. Body, fins, and fuzing make up remaining weight. The burster tube can be seen in the vented ZAB-500 SH on the left. (Author's photograph.)

Common Fuze Configurations: PD fuzing.

General Safety Precautions:

- HE, frag, movement, fire.
- Safety precautions for fuze and igniter, if present.

4. Category: Bomb. Group: Practice: Designed to fall with the same ballistic characteristics as the live bomb it mimics, minus the destructive effects. Some have all the hazards associated with the live bomb, while others possess no threats at all.

4.a. Category: Bomb. Group: Practice with Explosives or Spotting Charge: May be full sized or small in size weighing only a few kilos or pounds. Practice bombs may contain inert fillers such as sand or concrete to simulate explosives weight. Other designs contain a live fuze with booster to initiate an explosives charge, or propel chlorosulphonic acid (FS), titaniumtetracloride, or other spotting materials to identify the point of impact at great distance (Figures 8.10 and 8.11).

Figure 8.10 Top-to-bottom: Bomb Dummy Unit (BDU) 33, 25lb practice bomb. MK 106, 5lb practice bomb. MK 3, 3lb practice bomb. Example of a signal cartridge that may contain Red Phosphorus (RP) or titaniumtetracloride. (Author's photograph.)

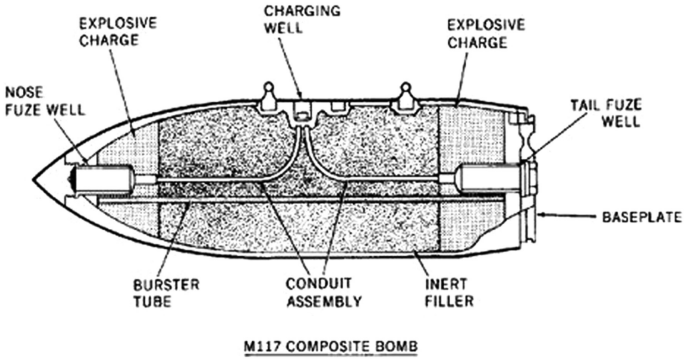


Figure 8.11 U.S. M117 "composite" practice bomb contains 67lb (30.4kg) of high explosives. Practice means practice, it does not mean inert. (From U.S. Military TM.)

General identification features include:

Materials and Appearance:

- Construction features consistent with the bomb they are designed to imitate.

Markings:

- Blue or green with white markings are common.
- Other stamped or stenciled marking may be present on the base or between the lugs.

Common Fuze Configurations: If fuzed, the fuze will be the same type employed on the bomb being imitated.

General Safety Precautions:

- Movement.
- Observe all applicable safety precautions for the live bomb until positive identification is made.
- HE, frag, ejection, fire if a spotting charge is present.
- Chemical if spotting charge functions.
- Safety precautions for fuze, if present.
- Practice means practice, it does not mean inert.

4.b. Category: Bomb. Group: Practice, Inert: Some are full sized, while others weigh only a few kilos or pounds. Inert practice bombs contain fillers such as sand or concrete to simulate explosives weight. As shown in Figure 8.11, positive identification is imperative.

General identification features include:

Materials and Appearance:

- Construction features consistent with the bomb they are designed to imitate.

Markings:

- Blue or green with white markings are common.
- Other stamped or stenciled marking may be present on the base or between the lugs.

Common Fuze Configurations: None.

General Safety Precautions:

- Movement.
- Observe all applicable safety precautions for the live bomb until positive identification is made.

Introduction: Aerial Dispensers

Dispensers are hollow containers, filled with a payload of submunitions or scatterable mines. Other names for aerial dispensers include Cluster Bomb Unit (CBU) and Aerial Stores Release or Suspension Unit (SUU).

Upon functioning, a dispenser is designed to deploy its payload. For aerial dispensers, the category is "Dispenser" and the two groups are:

1. Retained
2. Dropped

A dispenser is fixed on an aircraft with lugs or cleats. The primary difference between retained and dropped dispensers is that a retained dispenser remains fixed to the aircraft when its payload is deployed, while a dropped dispenser is deployed from the aircraft in a similar fashion as a bomb. Dispensers can be filled with a variety of payloads, including submunitions, mines, and other miscellaneous items such as leaflets.

Key Identification Features

Dispensers are fixed with lugs or cleats to secure them to an aircraft. These munitions are characterized by a thin-skin non-aerodynamic body shape that oftentimes includes unique markings.

The Seven-Step Practical Process Applied to Aerial Groups

Examples of different designs, features, color codes, markings, and construction features are provided throughout this section.

Step 1: Gather Information, Approach, and Initial Inspection: Attempt to identify from a safe distance with binoculars. Approach at a 45°angle from the rear, avoid side-ejecting ports.

With sketch pad and camera, document identifying features including fins, ejection ports, inspection windows, leaking material, color codes, stamped markings, construction features, seams, damage, signs of tampering or modification.

The three fastest means of researching an unknown aerial dispenser are:

1. The diameter at mid-body
2. The overall length and distance between lugs
3. Seams running the length of the body or other evidence of multiple-piece construction

Step 2: Determine Fuze Group, Type and Condition:

If a dispenser has been deployed (step 5), the fuze is considered armed. If the fuze is damaged, pins have been removed, or alterations have been made, it is considered armed. If visible, measurements for the fuze are taken separately from the munition.

In place of fuzing, some aerial dispensers incorporate explosive sequencers or initiators to deploy payloads.

Step 3: Determine Ordnance Category:

The category "aerial dispenser" and "deployed dispenser" are covered throughout this section.

Step 4: Determine Ordnance Group:

The identifiable characteristics associated with each aerial dispenser group are covered throughout this section.

Step 5: Determine if Munition was Deployed:

Inspect the dispenser for impact-related damage and missing pins or clips.

Step 6: Determine Safety Precautions:

Safety precautions for each aerial dispenser group are covered in this section. Once identified, these precautions must be adhered too.

Step 7: Research Literature and Identify the Munition:

Apply the totality of measurements, color codes, stamped markings, and construction features to determine the group, and positively identify the dispenser, payload, and fuzing configuration.

1. Category: Aerial Dispenser. Group: Retained: Provide a means of deploying large numbers of smaller ordnance items. Common methods of deployment include ram-air produced by the speed of the aircraft, strong springs to eject payloads, and smokeless powder-filled Cartridge Actuated Devices (CADs) that explosively eject munitions from the dispenser. Retained dispensers are not damaged during payload deployment. They are designed to be refilled and used numerous times.

General identification features include:

Materials and Appearance:

- Multi-piece, thin skin aluminum or tin body.
- No fuze.
- A canoe or tube-like configuration allowing payloads to be jettisoned from the rear or bottom of the dispenser.

Markings: Unpainted or colors matching the aircraft color scheme are common. Stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: No conventional fuzing. Electrical connection to the cockpit will control CADS or other means of deploying the payload. Proper deployment links the aircraft speed, altitude, and tactical saturation density, then deploys the payload.

General Safety Precautions:

- Movement, ejection.
- Safety precautions for any fuzing that may be present.
- Depending on the payload, HE, frag, jet, WP, fire, EMR, static, and chemical may apply.
- If jettisoned from an aircraft, consider all payload fuzing to be armed until proven otherwise.
- Safety precautions for fuze, if present.

2. Category: Aerial Dispenser. Group: Dropped: Deployed in the same manner as a bomb, dropped dispensers have fixed, low-drag fins for stabilization on the aft end and a nose fuze. Dropped dispensers come in a variety of shapes depending on the payload. Payload may consist of three to 3,000 submunitions or mines deployed when the fuze functions at a predetermined altitude above the target. Depending on the design, fuze functioning may initiate linear shaped charges to explosively open the dispenser lengthwise, or detonating cord to blow off the base and deploy the payload. Other dispensers deploy their contents when locks securing the outer body are released; other complex designs explosively inflate bladders to propel payloads outward (Figure 8.12).

General identification features include:

Appearance and Materials:

- Multi-piece, thin skin aluminum or tin body.
- Fins may be spring loaded and held in place by a band that is released when dropped.
- Lack of aerodynamic shape normally associated with aviation ordnance.

Figure 8.12 A CBU-52B/B dropped dispenser. Note the two-lug configuration, riveted fins, and noticeable break down the length of the body. (Author's photograph.)

Markings: Payload will define the color codes and markings. Stamped or stenciled markings and symbols may also be present.

Common Fuze Configurations: MT and ET fuzing.

General Safety Precautions:

- Movement, ejection.
- Depending on the payload, HE, frag, jet, WP, fire, EMR, static, and chemical may apply.
- If a dispenser impacts the ground unopened, consider all payload fuzing to be armed until proven otherwise.
- Safety precautions for fuze, if present.

Closing

Large bombs and dispensers are not commonly encountered outside military control, but smaller practice bombs are often recovered and pose a significant hazard. Until proven otherwise, always consider a dispenser or bomb, including smaller practice designs, to be in a hazardous condition until proven otherwise.

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Ordnance Category—Submunitions

9

Known U.S. cluster bombs dropped during Operation Desert Storm amounted to 47,167 units containing 13,167,544 bomblets. It has been estimated that 30,000 tons of unexploded ordnance [UXO] was scattered across Kuwait when the Gulf War ended. By February 1992 [one year after the war ended] more than 1,400 Kuwaitis had been killed in incidents involving UXO and landmines. Among the most dangerous items were cluster bomblets.

Rae McGrath, Cluster Bombs, Military Effectiveness and Impact on Civilians of Cluster Munitions (Landmine Action, 2000)

Introduction

The history of submunition development and deployment is difficult to track. Investigative reporter John Ismay is working on this issue and has uncovered some interesting facts. For example, the most often cited "first attack" is the German deployment of SD-2 "butterfly bombs" on the British towns of Grimsby and Cleethorps on June 13, 1943. For some reason the October 27, 1940 German attack on the British airfields at Ipswich and Wattisham with SD-2s is often overlooked. There are prior attacks but these earlier submunitions were largely repurposed mortar or artillery projectiles versus a specifically designed submunition. That said, the first high-explosive munition specifically designed for use as a submunition, mass-produced, and used in large numbers appears to be the German SD-2 (Figure 9.1).

Regardless of who made them first, submunitions are some of the most contemptible and technically advanced munitions made. If found outside military control, submunitions constitute a multitude of dangers as they are often designed to kill or injure personnel trained to clear them as stated in this quote.

A German prisoner of war told our bomb disposal people the Luftwaffe dropped some containers of butterfly bombs onto a race course near Paris in order to give their bomb disposal squads the experience of coping with them. The result was a number of German casualties. Very thorough.

Thomas A. Crawford, *Imitation is the Sincerest Form of Flattery*, Journal of the Company of Military Historians.

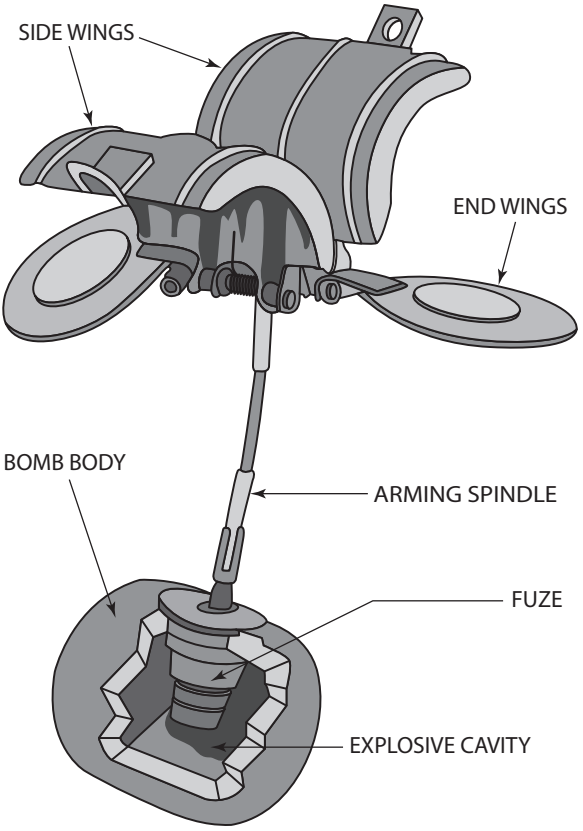

Figure 9.1 German SD-2 Butterfly bomb. The U.S. M83 is a "copycat"and incorporates a welded-seam on the body, an easy way to differentiate the two. (From U.S. Military TM.)

The statistics from the first Gulf War provided by Rae McGrath represent only those dropped by U.S. aviation assets. Not included in these numbers are submunitions deployed from projectiles, rockets, and guided missiles fired by U.S. forces, nor the submunitions deployed by all other countries involved. Mr. McGrath is absolutely correct that submunitions, also known as cluster bomblets, constituted a tremendous threat to Kuwaiti civilians. But as submunitions are generally small and lack a standardized shape or configuration, they are easily overlooked, concealed, or carried off as war trophies. As such, these munitions are commonly recovered in unexpected locations.

A few constants associated with submunitions include:

1. They are deployed from another munition.
2. They are usually deployed in enormous numbers to saturate large areas.
3. Fuzing ranges from extremely simplistic to highly sophisticated.

4. They tend to have very high "failure to function" or "dud" rates, often exceeding 20% of the payload.

For this chapter, the defining factors categorizing a munition as a "submunition" are:

1. The item is deployed from a projectile, rocket, missile, or aerial dispenser.
2. Once deployed from the dispenser, the munition is an independent, fully functional ordnance item.

There are exceptions and variations to these defining factors that may confuse accurate identification. First, the vernacular used to describe or define submunitions is generated by the category of dispenser from which they are deployed. The result is difficulty in researching an unknown munition that may be listed under lexicon classifying it as a bomblet, submunition, cluster munition, grenade, dispensed landmine, or other terms. In order to avoid confusion, the term "submunition" is used throughout this text. "Grenades" are defined as the hand, rifle, and projected grenades covered in Chapter 6; landmines are covered in Chapter 10. There is some gray area concerning the defining differences between submunitions and dispensed landmines. In an attempt to bring some clarity to a rather complicated classification, an example of a "family" of dispensed mines is covered in the landmines chapter. See Appendices D and E for information on marking schemes.

Key Identification Features

As a rule-of-thumb, the identifying characteristics of a munition are generated by the physics and engineering associated with the category and group to which it belongs. However, as submunitions are not fired or shot, but rather carried to the target area inside another munition, these typical characteristics are absent, and in many cases submunitions are completely devoid of any color codes or stamped markings.

Submunitions come in many shapes, sizes, and can be deployed many different ways. If present, all the definitions associated with identifiable ordnance characteristics, such as ogive, bourrelet, warhead, body, motor, fin assembly, etcetera, apply to submunitions. When inspecting an unknown munition that could be a submunition, focus on these two areas:

1. If unable to determine the category or answer the question "how was this deployed?"
2. Try to determine the group, which will reduce the number of possibilities when researching.

The Seven-Step Practical Process Applied to Submunitions

Examples of different designs, features, color codes, markings, and construction features are provided throughout this chapter.

Step 1: Gather Information, Approach, and Initial Inspection: Attempt to identify from a safe distance with binoculars. Approach at a 45° angle from the rear, avoiding venturis and fuze sensing elements.

With sketch pad and camera, document identifying features including fins, venturis, leaking material, color codes, stamped markings, construction features, damage, signs of tampering or modification. Also note the location, diameter, and length of each component and the material it is made from.

The three fastest means of researching an unknown submunition:

1. The overall diameter and length.
2. The shape and appearance.
3. Means of stabilization; i.e., fins, ribbon, parachute, or other means. If not present, does the munition spin?

Step 2: Determine Fuze Group, Type, and Condition: If a submunition has been deployed (step 5), the fuze is considered armed. If the fuze is damaged, pins have been removed, or alterations have been made, it is considered armed. If visible, measurements for the fuze are taken separately from the munition.

A common fuzing configuration for submunition payloads is to load one-third with impact fuzing, one-third with time fuzing set for random times, and one-third to arm upon impact and function when moved via anti-disturbance (A/D) fuzing.

Step 3: Determine Ordnance Category:

The category "submunition" is covered throughout this chapter. Repurposed projectiles deployed as submunitions usually have the rotating band removed, but the seat or groove where it would have been will help determine the original identity of the munition and from that, its submunition configuration.

Step 4: Determine Ordnance Group:

The identifiable characteristics associated with each submunition group are covered throughout this chapter.

Step 5: Determine if Munition was Deployed:

Unlike other munitions, any submunition found outside its dispenser is considered armed. Additionally, if an aerial dispenser fails to deploy its payload and impacts the ground, every submunition inside the dispenser is considered armed.

Step 6: Determine Safety Precautions:

Safety precautions for each submunition group are covered in this chapter. Once identified, these precautions must be adhered to.

Step 7: Research Literature and Identify the Munition:

Apply the totality of measurements, color codes, stamped markings, and construction features to determine the group, and positively identify the munition and possible fuzing configuration.

Groups

Any small munition can be repurposed for deployment from a dispenser and the submunition category covers thousands of different configurations. In order to provide a coherent flow, the submunition category is divided into the following primary and supplemental groups:

1. High Explosive (HE)
   a. HE-Fragmentation and HE-Incendiary (HEI)
   b. Bounding Fragmentation
   c. Fuel–Air Explosive (FAE)
2. High-Explosive-Anti-Tank (HEAT) and Explosively Formed Projectile (EFP)
3. Incendiary
4. Practice

1. Category: Submunition. Group: HE: Designed to explode and destroy targets with blast, fragmentation, and thermal effects. Explosive fillers in these submunitions range from less than an ounce to many pounds, in solid, pliable, or liquid form.

It is crucial to understand the initial purpose of these munitions to appreciate how they have evolved. For example, the German SD-2 "Butterfly" bomb (Figure 9.1) was designed to destroy equipment, cause casualties, and most importantly, disrupt operations. To accomplish this, four fuzing types were used.

1. Impact: Immediate casualty effect
2. Short-Time-Delay: Psychological effect
3. Long-Time-Delay Self-Destruct: Area denial, slow recovery operations and cause casualties
4. Anti-Disturbance (A/D): Hamper cleanup and recovery operations by specifically targeting personnel tasked to clear UXOs

The success of this mixed-batch fuzing approach resulted in it becoming a standard configuration for many submunition designs used today (Figures 9.1 and 9.2).

Figure 9.2 Top, left to right: U.S. submunitions, commonly referred to as the "golfball," baseball," and "softball" due to the relative sizes. Bottom left to right: Russian AO-2 and cutaway BLU-61 "softball." After deployment, the external flanges make these munitions spin, arming the fuze. (Author's photographs.)

1.a. Category: Submunition. Group: HE-Frag & HEI:

Submunitions have evolved to maximize effects and streamline logistics with multi-target configurations. These designs allow one munition to be effectively deployed against many different targets. As such, HE-Frag and HEI submunitions usually have high-explosives surrounded by a robust fragmentation sleeve for anti-personnel and a pyrophoric liner for anti-materiel. The metals used for anti-materiel include, aluminum, magnesium, and zirconium. These metals are so common that all HE submunitions are assumed to possess this hazard until proven otherwise. For this reason, HE and HEI submunitions are grouped together.

General identification features include (Figures 9.1 and 9.2):

Materials and Appearance:

- Heavy duty, multi-piece construction.
- External serrations may be visible.
- Means of arming with components that spin or move.
- Lack of orientation (the SD-2 design is an exception).
- Lack of characteristics used to determine how the munition was deployed and the category it falls under.

Markings: The body may be unpainted or painted colors inconsistent with common schemes. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: Internal fuzing that cannot be seen. Possibilities include:

1. All-Ways-Acting Impact.
2. Short-Time-Delay.
3. Long-Time-Delay-Self-Destruct (S/D).
4. Anti-Disturbance (A/D).

General Safety Precautions:

- HE, frag, fire, movement.
- Safety precautions for fuze, if present.
- Due to the high percentage of internal fuzing, apply Wait-Time (W/T), and Booby Trap (B/T) for the Anti-Disturbance (A/D) until these threats are ruled out.

1.b. Category: Submunition. Group: HE-Bounding: A common configuration includes a body with a means of orientation and a pressure-plate. Upon impact, the pressure plate is struck, initiating an ejection charge that ignites a pyrotechnic delay, while ejecting the warhead that bounds approximately 3 to 4ft (1 meter) from the submunition body before detonating (Figure 9.3). The BLU-77/B in Figure 9.8 contains a fuze capable of target differentiation, to allow the munition to bound when a soft target is impacted.

General identification features include:

Materials and Appearance:

- Lightweight, multi-piece construction.
- Visible frag-ball on one side of munition.
- Means of arming with components that spin or move.
- Means of orientation.
- Lack of characteristics used to determine how the munition was deployed and the category it falls under.

Markings: The body may be unpainted or painted colors inconsistent with common schemes. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: PD, short PTTF, S/D.

General Safety Precautions:

- HE, frag, ejection, movement.
- Short W/T for ejected warhead.
- Safety precautions for fuze, if present.
- Due to the high percentage of internal fuzing, apply W/T, and B/T for the A/D feature until these threats are ruled out.

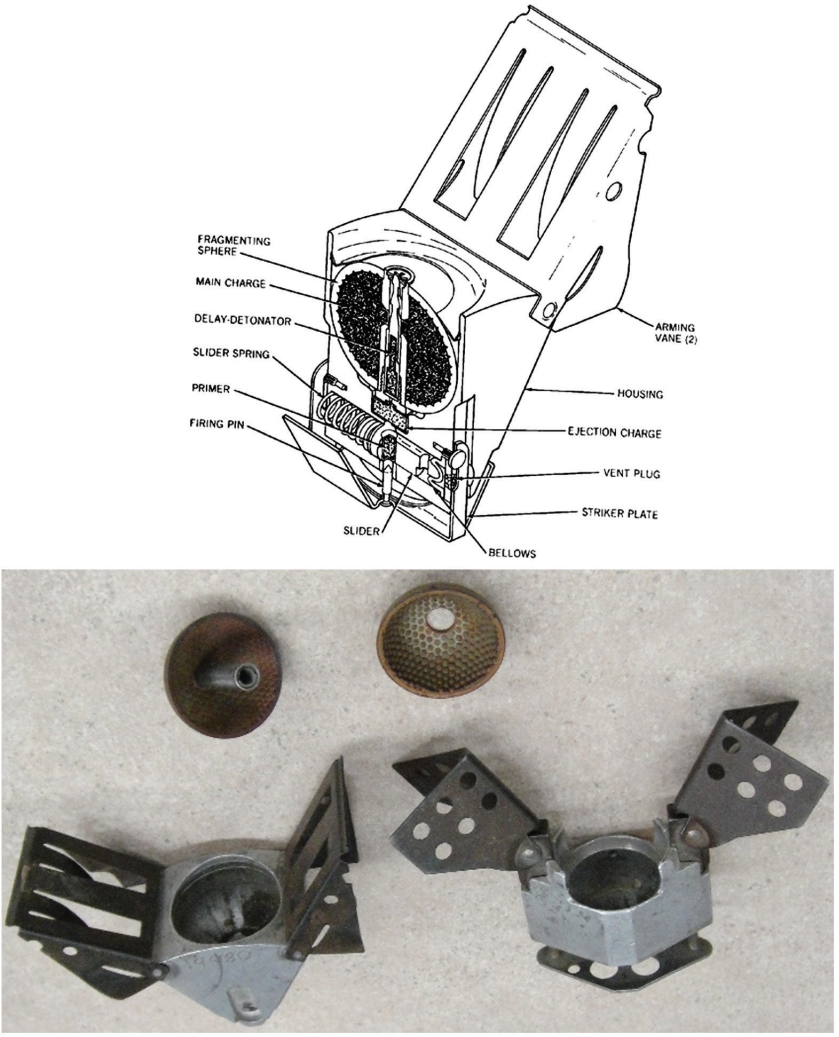

Figure 9.3 Bounding-fragmentation submunitions. Top: M36, if deployed from 105mm projectile, or BLU-18 if dispersed from a helicopter mounted dispenser (From U.S. Military TM). Bottom, left to right: M36 and M39, displayed with disassembled fragmentation ball. (Author's photograph.)

1.c. Category: Submunition. Group: Fuel-Air-Explosive (FAE): Similar in construction to thermobaric warheads of other ordnance categories, FAE designs incorporate a time element to ensure a proper fuel–air, or stoichiometric ratio exists before functioning for maximum explosive effect.

Upon impact, a burster tube running down the center of the munition functions to rip open the thin-skinned body while aerosolizing the liquid fuel. As the fuel mixes with the air in the environment, "cloud detonators" arm and function as a stoichiometric ratio is reached (Figure 9.4). The result is a tremendous explosion and the generation of a strong shock-front designed to clear areas for helicopters to land in jungle and wooded terrain. FAE munitions are seldom used and the liquid fuel results in leaks, thus restricting storage times.

General identification features include:

Materials and Appearance:

- Thin-skinned metal body.
- Color codes inconsistent with common schemes.
- A parachute or other means of orientation.
- May have a probe or standoff for the fuze.
- A filler plug on the body.

Markings: The body may be unpainted or painted colors inconsistent with common schemes. Other colors, stamped or stenciled markings, and symbols may be present.

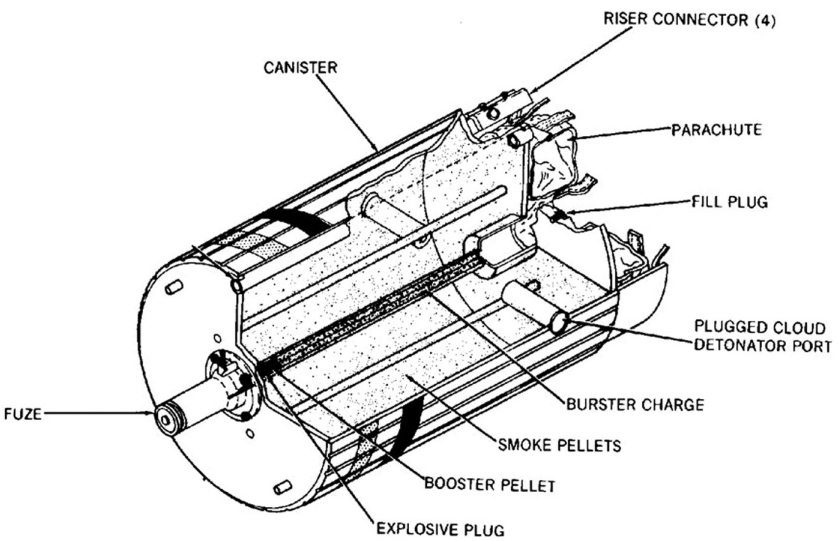

Figure 9.4 U.S. BLU-73 FAE Bomb. The CBU-72 dispenser contains three FAE bombs, each weighing approximately 100lb (45kg). Upon functioning, each munition produces the force of 250lb (113kg) of TNT. (Author's photograph.)

Common Fuze Configurations: Impact fuzing to disperse the fuel, and cloud detonators to initiate the FAE.

General Safety Precautions:

- HE, frag, fire, chemical, movement.
- Filler presents a significant Fire and Chemical threat.
- Safety precautions for fuze, if present.
- Due to the high percentage of internal fuzing, apply W/T, and B/T for the A/D feature until these threats are ruled out.

2. Category: Submunition. Group: HEAT & EFP: Contain a shaped charge or EFP to defeat armored and other hardened targets. In order to function correctly and maximize penetration, a standoff spike or hollow ogive is required.

Older HEAT submunitions were configured to maximize armor penetration, with little consideration of fragmentation production. Newer designs incorporate multipurpose configurations to allow one munition to be effectively deployed against many different targets. In order to do this successfully, a submunition must contain the required components in the correct configuration to produce these effects:

1. Anti-Personnel: High explosives surrounded by a robust fragmentation sleeve.
2. Anti-Tank: A shaped-charge for anti-armor.
3. Anti-Materiel: A pyrophoric liner. Metals used include aluminum, magnesium, and zirconium. These anti-materiel additives are so common that all HE submunitions are assumed to possess this hazard until proven otherwise. For this reason, HE and HEI submunitions are grouped together.

The multi-function characteristic has driven changes to naming conventions, such as High-Explosive Dual Purpose (HEDP). HEDP and HEAT mean the same thing, but HEDP is becoming more common with projected grenades and submunitions. For this text, a submunition designed to defeat armor will be referred to as a "HEAT" submunition. Figures 9.5 through 9.9, and include examples of various HEAT submunition designs. Figure 9.10 shows an example of a highly sophisticated submunition design.

General identification features include:

Materials and Appearance:

- Heavy or light materiel, multi-piece construction.
- Break in the major diameter forward of the bourrelet (Figure 9.7).
- Standoff spike (Figure 9.9).
- Hollow ogive, crimped or screwed to the body.

- Color codes inconsistent with common schemes.
- Means of orientation (Figures 9.6 through 9.9).
- May have spanner holes where components meet.

Markings: The body may be unpainted or painted colors inconsistent with common schemes. Other colors, stamped or stenciled markings, and symbols may be present.

Common Fuze Configurations: BD, PIBD, and long delay S/D fuzing. In order to effectively function against different targets, these munitions may contain more than one fuze.

General Safety Precautions:

- HE, frag, jet, movement.
- Many PIBD fuzing systems incorporate PE. Adhere to the PE, EMR, static; until PE is conclusively ruled out.
- Safety precautions for fuze, if present.
- Due to the high percentage of internal fuzing, apply W/T, and B/T for the A/D feature until these threats are conclusively ruled out.

Figure 9.5 Yugoslavian KB-1, HEAT submunition. (Author's photograph.)

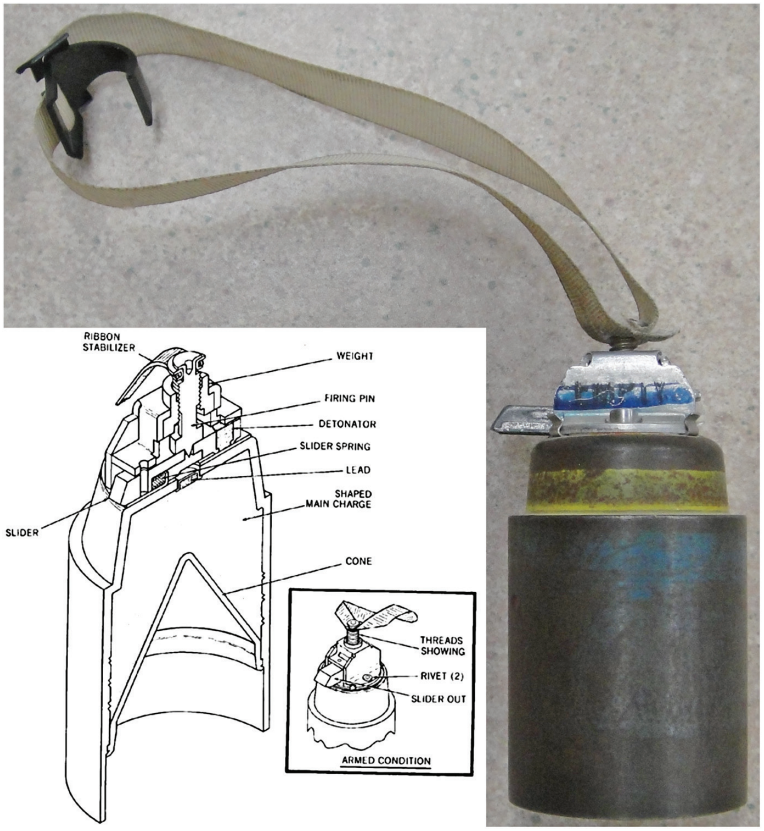

Figure 9.6 U.S. M42, M46, or M77, HEAT submunition. The yellow band is consistent with the M46. (Author's photograph, and from U.S Military TM.)

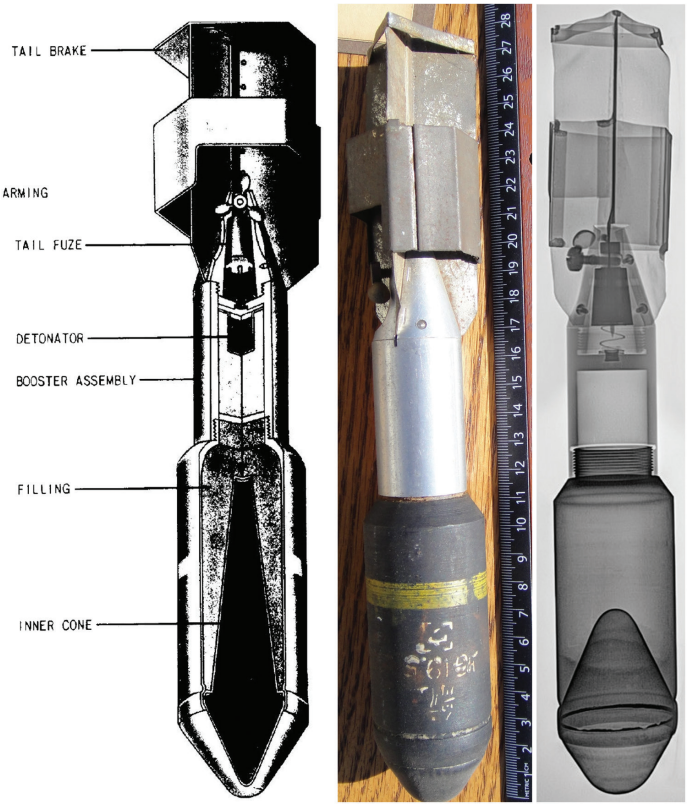

Figure 9.7 Line drawing, picture, and x-ray of a WWII-era, Japanese, Type-2, HEAT submunition. (From U.S. Military TM, author's photograph, x-ray provided by Mike Eldredge on behalf of the ATF National Center for Explosives Training and Research.)

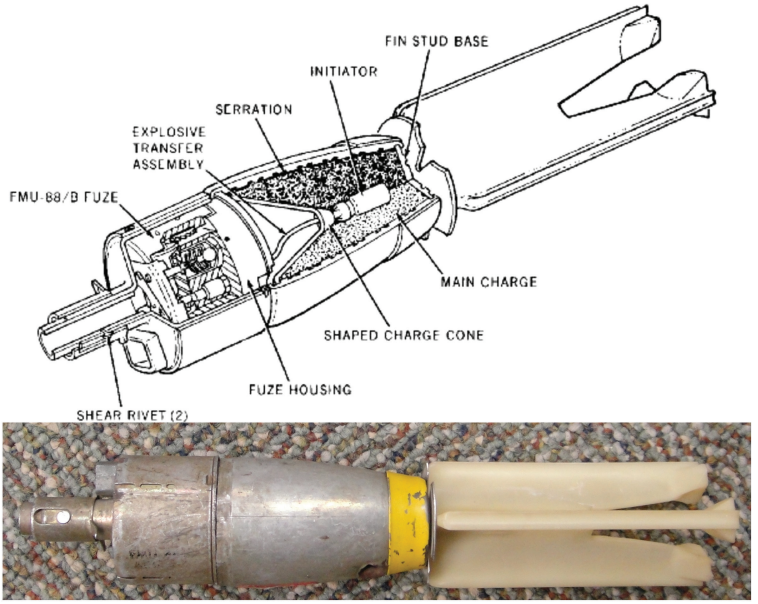

Figure 9.8 U.S. BLU-77/B is an obsolete Anti-Personnel-Anti-Material (APAM) munition. Upon impact with a hard target the PIBD fuze will function, directing its shaped charge against the target. If a soft target such as sand or dirt is struck, an explosive charge in the fuze housing ejects the warhead before functioning so fragmentation and zirconium are not absorbed by the ground. (From U.S. Military TM, and author's photograph.)

Figure 9.9 HEAT Submunitions with different means of orientation, left to right: British No.1 MK1, U.S. MK118 "Rockeye" and the French GR-66 "Belouga." (Author's photographs.)

Figure 9.10 U.S. BLU-108. After deploying from an aerial dispenser, a parachute controls descent until a radar altimeter initiates the deployment sequence at a predetermined height. The four submunitions are thrown out like skeet and use an infrared (IR) sensor to identify valid targets within their trajectory. Once identified, the warhead functions while the submunition is airborne (airburst) firing an EFP through the top of the target. If a target is not identified, the munition is designed to self-destruct or render itself safe. (Author's photographs.)

3. Category: Submunition. Group: Incendiary: Usually contain thermite or thermate mixtures that burn at approximately 4000°F and pose a significant fire hazard. Figure 9.11 shows the German B-1E incendiary submunition alongside its American M126 counterpart.

General identification features include:

Materials and Appearance:

- Light, thin-skin metal body.
- Multi-piece construction.
- Fins or other means of orientation on many designs.

Markings: Usually unpainted metal with no markings. Other colors, stamped or stenciled markings, and symbols may be present.

Common Fuze Configurations: BD or PD fuzing.

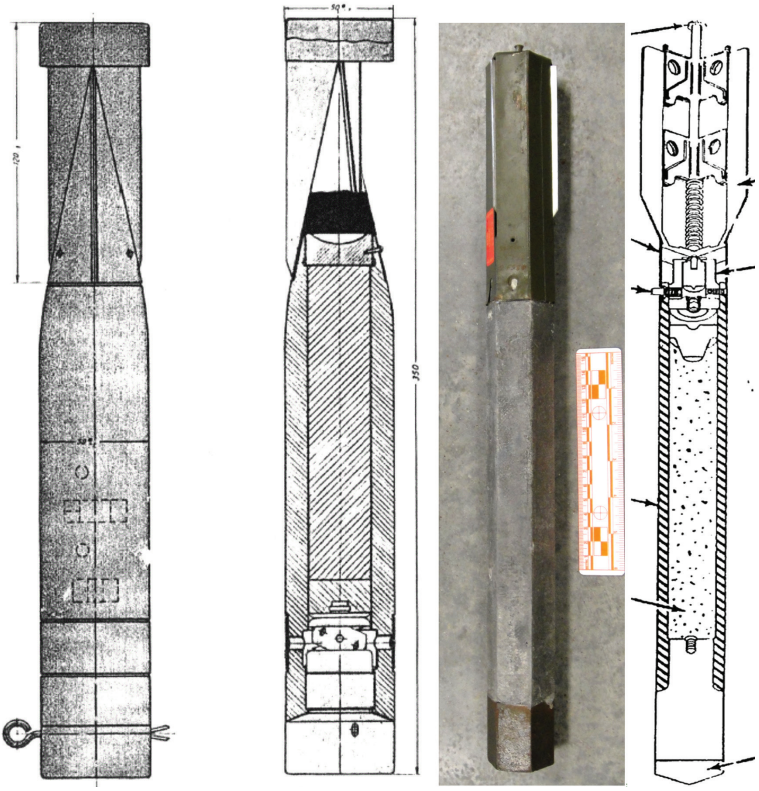

Figure 9.11 WWII-era incendiary submunitions, left to right: German B-1E, 1kg (2.2lb). U.S. M126, 4lb (1.8kg) picture and line drawing. (From U.S. Military TM, and author's photograph.)

General Safety Precautions:

- Fire, movement.
- Some designs incorporate WP in the fuzing.
- Safety precautions for fuze, if present.

4. Category: Submunition. Group: Practice: Designed to fall with the same ballistic characteristics as the live submunition it mimics, minus the destructive effects. Practice submunition may contain inert fillers or a spotting charge ejected by a fully functional fuze while other designs are hollow versions of the live munition. In previous chapters, Figures 4.23, 4.24, and 5.2 show submunitions in predeployment configurations.

General identification features include:

Materials and Appearance:

- Construction features consistent with the submunition they are designed to imitate.

Markings: Unpainted, or painted colors that may or may not be consistent with common schemes. Other stamped or stenciled markings may be present on the base or between the lugs.

Common Fuze Configurations: If fuzed, the fuze will be the same type employed on the submunition being imitated.

General Safety Precautions:

- Movement.
- Observe all applicable safety precautions for the live bomb until positive identification is made.
- HE, frag, ejection, fire if a spotting charge is present.
- Chemical if spotting charge functions.
- Safety precautions for fuze, if present.
- Practice means practice, it does not mean inert.

Closing

Submunitions do not always possess the commonly applied identification features since many are repurposed munitions from other ordnance categories. As such, identification may be difficult and many are mistaken for children's toys.

Do not rush when researching an unknown munition. Always consider a submunition to be in a hazardous condition until proven otherwise.

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Ordnance Category—Landmines

10

Munitions deployed on, under, or near the ground that are initiated by the presence, proximity, or contact of a person regardless of whether they are improvised or not are anti-personnel landmines.

Definition from: The Anti-Personnel Mine Ban Convention (APMBC)

Introduction

As defined by the APMBC, conventional landmine use dates back to the American Civil War when a design patented as "sub-terra boobytraps" was submitted by Brigadier General Gabriel Rains, and authorized for use by the Confederate secretary of war. With the Civil War raging and Confederate forces losing ground, the thought of deploying such an immoral or cowardly weapon restricted its use to parapets and roads in order to slow or stop an assault. Though the nefarious reputation stuck, the restrictions did not, and today landmines are some of the most commonly encountered ordnance items outside military control.

Landmines are unique as they are the only ordnance category specifically designed to be functioned by their intended victim. Landmines cause a number of tactical problems, but the APMBC definition also mentions "improvised" which can become a source of confusion. Any improvised landmine capable of exploding is classified as an improvised explosive device (IED), which is not ordnance. The landmines covered in this chapter focus on conventional munitions manufactured by an internationally recognized country. However, for reference, examples of a mass-manufactured landmine made in an improvised fashion is provided in Figure 10.1. Another common issue associated with landmines are copycat designs, which may appear the same externally, but have completely different internal configurations (Figure 10.2).

Landmine designs vary and they can be hand placed, mechanically deployed from vehicles, or deployed from dispensers in the same manner as submunitions. With so many designs, it is impossible to cover every landmine;

Figure 10.1 Improvised landmines recovered in Afghanistan. Referred to as "AFPAK" and a number, original designs (on right) were similar to the Russian PMN. Later designs with larger bodies employ fuzing consistent with the Chinese Type-72. (Author's photographs.)

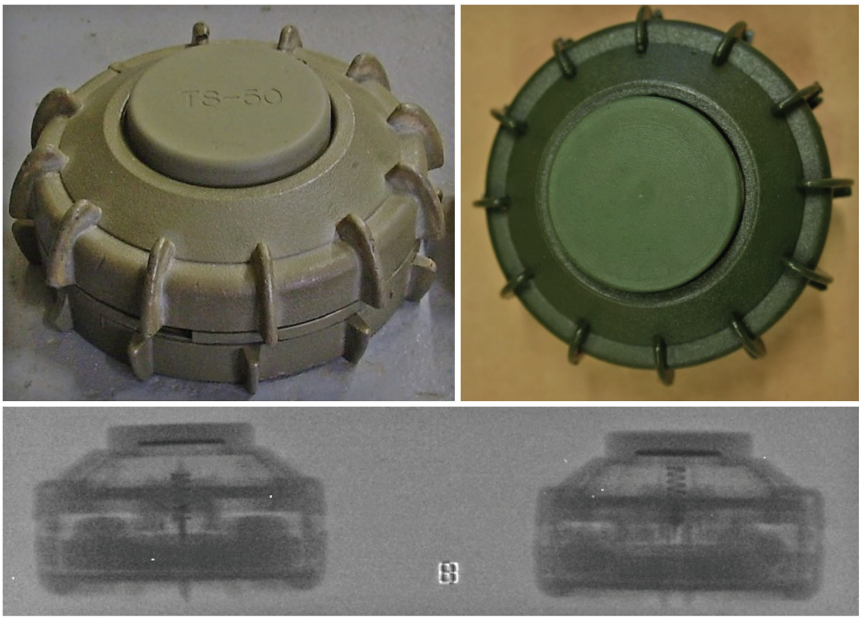

Figure 10.2 Top-left: Italian TS-50 APERS mine with arming cap removed. Right: Iranian YM-1 copycat design with arming cap removed. Bottom: X-ray of two YM-1 landmines, note the depressed spring on the left, which was stepped on, but a detonator was not installed. (Author's photographs.)

as such, this chapter focuses on shapes, construction features, materials, and functional designs that may help establish the group and safety precautions associated with an unknown landmine.

For this chapter, the defining factors that categorize a munition as a "landmine" are:

1. Specifically designed to be initiated by the victim
2. Used for land-based deployment

There are ordnance configurations that can confuse this definition and complicate accurate identification. For example, a U.S.-made 2,000-pound bomb dropped with a magnetic influence fuze (see Chapter 3) will function as a magnetic influence mine.

There is also some gray area concerning the defining differences between submunitions and dispensed landmines. In an attempt to clarify a complex classification, examples of "a family of scatterable mines" (FASCAM) is provided throughout this chapter. See Appendices D and E for information on marking schemes.

Key Identification Features

Landmines are designed to be hidden or appear benign when deployed. As such, they come in many shapes and sizes and can be deployed in a number of different ways. But with most mines being hand-placed and functioned by pressure applied to a pressure plate on top, most landmines have a non-aerodynamic round body with two flat sides.

Landmine Sections and Defining Features

Body: Most landmines are constructed of metal or plastic, but glass, pottery, wood, and other materials have also been used. The shape and texture of the outer body is designed to decrease ground settling around it after being laid, as well as to slow deterioration. On larger mines, a common design is a primary fuze functioned by a pressure plate, and two or three additional fuze wells for boobytraps to target combat engineers or deminers attempting to neutralize them.

Fuze: Unlike other ordnance categories, hand-placed landmines are usually direct-armed when a single pin, clip, collar, or cap is removed. Most large landmines contain auxiliary fuze wells for boobytrap fuzing to be installed, which can lead to a tremendous amount of field improvisation. Accordingly, always consider the possibility of hidden or unseen fuzing and treat all mines as boobytrapped until proven otherwise.

Depending on the intended target, landmines can be initiated by pressure, pull, pressure release, tension release, or tilt resulting from the actions of a person or vehicle. Additionally, there are extremely complex designs, for example, influence fuzing can be configured so a magnetic influence fuze can turn off and "sleep" to save battery power. When a potential target comes near, a seismic sensor "awakens" the magnetic sensor, which immediately scans the area and functions if an appropriate target is within range. If the target does not come within range, the fuze can go back to sleep. If a target never comes near the mine and its power source is almost depleted, it will self-neutralize, or initiate a Self-Destruct (S/D) feature.

The Seven-Step Practical Process Applied to Landmines

Examples of different designs, features, color codes, markings, and construction features are provided throughout this chapter.

Step 1: Gather Information, Approach, and Initial Inspection: If not specifically trained, do not approach a deployed landmine. Attempt to identify from a safe distance with binoculars. If the landmine has a directional feature, approach at a 45° angle from the rear, avoiding fuze sensing elements.

With sketch pad and camera, document identifying features including size, color codes, stamped markings, construction features, damage, signs of tampering, or modification. Attempt to determine how long it has been in place.

The three fastest means of researching an unknown landmine are:

1. The diameter at the widest point and height
2. Body construction features and materials
3. Fuze configuration

Step 2: Determine Fuze Group, Type, and Condition: If a landmine is deployed (step 5), the fuze is considered armed. If the fuze is damaged, pins have been removed, or alterations have been made, it is considered armed. If the entire landmine cannot be inspected, assume there are additional armed fuzes present. If visible, measurements for the fuze are taken separately from the munition.

Step 3: Determine Ordnance Category:

The category "landmine" is covered throughout this chapter.

Step 4: Determine Ordnance Group:

The identifiable characteristics associated with each landmine group are covered throughout this chapter.

Step 5: Determine if Munition was Deployed:

A landmine found outside controlled storage should be considered deployed. Inspect the munition for missing pins or clips and deployed tripwires.

Step 6: Determine Safety Precautions:

Safety precautions for each landmine group are covered in this chapter. Once identified, these precautions must be adhered to.

Step 7: Research Literature and Identify the Munition:

Apply the totality of measurements, color codes, stamped markings, and construction features to determine the group, and positively identify the munition and possible fuzing configuration.

Groups

In order to provide a congruent flow, the projectile category is divided into the following primary and supplemental groups:

1. Anti-Personnel (APERS or AP)
   a. Blast
   b. Fragmentation
   c. Bounding fragmentation
   d. Directional fragmentation
2. Anti-Tank (AT)
   a. Blast
   b. Explosively Formed Projectile (EFP) or shaped charge
3. Practice

1. Category: Landmine. Group: AP or APERS: Designed to explode and injure or kill personnel with blast and fragmentation. Explosive fillers range from approximately 1oz to 3lb (28.35 to 1,361gr). Fuze settings and types vary, but direct pressure of 5 to 35lb (2.27 to 15.9kg) or tripwire pull pressure of 8oz to 8lb (.22 to 3.6kg) are common force requirements. APERS mines are designed to be deployed in high numbers and also used in conjunction with AT mines as a deterrent to clearance operations.

1.a. Category: Landmine. Group: AP, Blast: A non-fragmentation-producing mine designed to target personnel with explosive blast effects. Most designs are deployed just below the surface of the ground. When a person steps on the mine, the explosive force follows the easiest path of resistance, upward into the victim, thus maximizing the energetic potential. As seen in Figures 10.1 through 10.3, these mines are usually simplistic, inexpensive, easily deployed in large numbers, and thus commonly encountered outside military control.

General identification features include:

Materials and Appearance:

- Deployed below the surface of the ground.
- Constructed of painted metal or colored plastic.

- Multi-piece construction.
- Means of manual arming.

Markings: Tan, brown, or green body with white or black markings are common. Dispensed mines may be unpainted. Other colors, stamped or stenciled markings, and symbols may also be present, such as the indented "TS-50" in Figure 10.2.

Common Fuze Configurations: Direct pressure. Pressure plate may be visible, but fuzing is usually internal. Self-destruct and anti-disturbance (A/D) fuzing is included on some designs.

General Safety Precautions:

- HE, B/T, movement.
- Frag, for secondary frag from the environment.
- Safety precautions for fuze, if present.
- Treat all landmines as boobytrapped until conclusively proven otherwise.

1.b. Category: Landmine. Group: AP-Fragmentation: Designed to kill or injure personnel with explosive blast and fragmentation effects. Most designs are deployed just above the surface with tripwires to extend the coverage area. When a person hit a tripwire or otherwise functions the mine, fragmentation is dispersed in all directions against the victim and everyone near the victim. These mines are simplistic, inexpensive, easy to deploy, and commonly encountered outside military control (Figure 10.4).

The AP version of the FASCAM mentioned in the introduction, including the air-dropped "Gator," and helicopter delivered or ground-placed "Volcano"

Figure 10.3 P4MK1, Pakistani APERS mine. The white plastic shipping cover on the left also serves as the arming cap as the mine is armed when this piece is unscrewed and removed prior to deployment. (Author's photograph.)

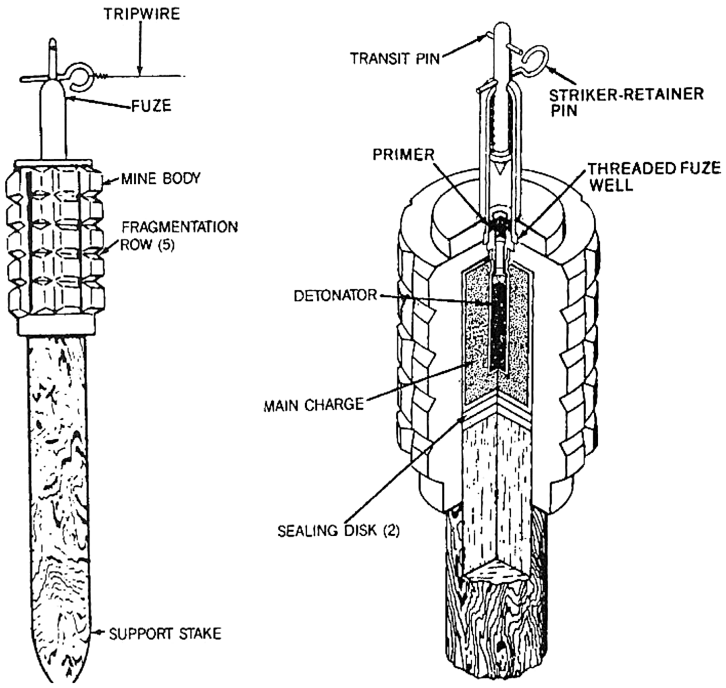

Figure 10.4 Russian POMZ-2M, APERS fragmentation mine containing a 1.65lb (.75kg) HE main charge. The number of fragmentation rows may differentiate similar designs from other countries. For example, Russian designs tend to incorporate five rows of fragmentation. (From U.S. Military TM.)

systems, will be used as an example, as all three deploy the same munitions. The BLU-92/B is the AP fragmentation-producing dispensed landmine used with these systems (Figure 10.5). After deploying and impacting the ground, eight 20ft (6m) tripwires deploy to cover a large area. Containing almost 1lb (0.4kg) of high-explosive, the fragmentation threat from these mines extends well beyond tripwire length.

General identification features include:

Materials and Appearance:

- Deployed above the surface of the ground.
- Heavy duty construction, may have external serrations.
- Constructed of painted metal or colored plastic.
- Tripwire, multi-prong-like top on fuze (Figure 10.4).
- Means of manual arming.

Markings: Tan, brown, or green body with white or black markings are common. Dispensed mines may be unpainted. Other colors, stamped or stenciled markings, and symbols may also be present.

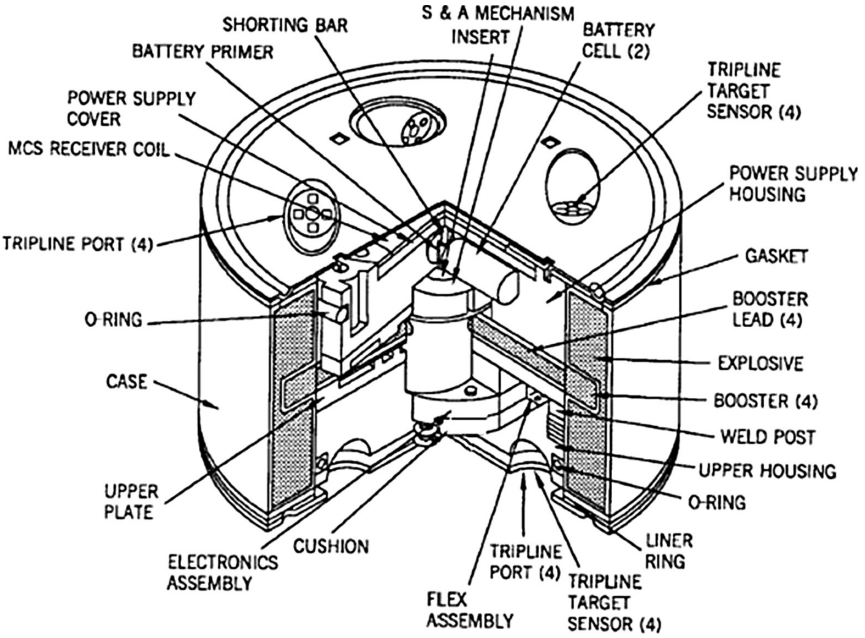

Figure 10.5 U.S. BLU-92/B, APERS dispensed mine with eight tripwires that deploy to cover a large area. (From U.S. Military TM.)

Common Fuze Configurations: Tripwires set for pull or tension release (Figure 10.4). Self-destruct and anti-disturbance (A/D) fuzing is included on some designs (Figure 10.5). In Figure 10.5, the mine contains a Safe and Arming (S&A) mechanism versus a conventional landmine fuze.

General Safety Precautions:

- HE, frag, B/T, movement.
- Safety precautions for fuze, if present.
- Treat all landmines as boobytrapped until conclusively proven otherwise.
- Do not cut tripwires until identity is confirmed.

1.c. Category: Landmine. Group: AP-Bounding Fragmentation: Deployed below the surface, and upon functioning, eject or bound a warhead upward 3 to 4ft (1m) above the ground before detonating. Nicknamed a "Bouncing Betty," this mine is not covered under fragmentation landmines due to its unique configuration. The warhead and outer body are usually constructed of metal or plastic. Some designs incorporate repurposed munitions such as a 60mm HE mortar, where others are purpose-built, as shown in Figure 10.6. Explosive weights vary from a few ounces to over 7lb (3.3kg).

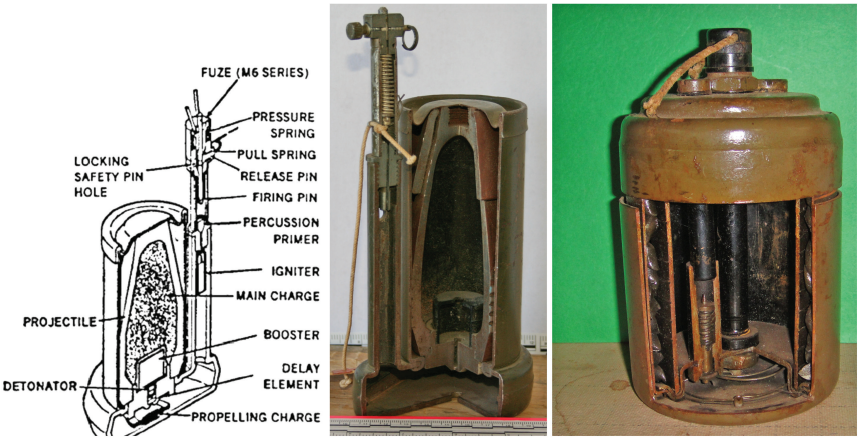

Figure 10.6 Left to right: U.S. M2 Series Bounding Fragmentation Landmine with an M6 Series fuze. (From U.S. Military TM). Cutaway of an M2 Series mine incorporating a 60mm HE mortar body for the warhead. And a Czech Republic PP-MI-SR mine. (Author's photographs.)

General identification features include:

Materials and Appearance:

- Deployed below the surface.
- Heavy duty construction.
- Constructed of painted metal or colored plastic.
- Multi-piece construction.
- Tripwire, multi-prong-like top on fuze (Figure 10.6).
- Means of manual arming.

Markings: Tan, brown, or green body with white or black markings are common but may be unpainted. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: The prongs at the top of the fuze (Figure 10.6) will function when direct pressure is applied to the prongs or a tripwire attached to them. Tripwires can also be attached to other sections of some fuzes and set for pressure or tension release.

A common fuzing configuration is where the fuze functions to initiate a black powder ejection charge. Upon functioning, the ejection charge deploys the warhead that travels 3 to 4ft (1m) before functioning from a cable anchored to the body that initiates a pull-friction fuze, or via a pyrotechnic delay ignited when the warhead was being ejected.

General Safety Precautions:

- HE, frag, B/T, ejection, movement.
- Short W/T for ejected warhead.
- Safety precautions for fuze, if present.
- Treat all landmines as boobytrapped until conclusively proven otherwise.
- Do not cut tripwires until identity is confirmed.

1.d. Category: Landmine. Group: AP-Directional Fragmentation: Deployed above ground, these fragmentation-producing mines are designed to kill or injure personnel with blast and fragmentation effects. Nicknamed "Claymores," these mines are not covered under fragmentation landmines due to their unique configuration. Designs vary, but all include a layer of fragmentation, backed by explosives in a round or rectangular shaped body, with a concave or convex front (Figures 10.7 and 10.8). Explosive weights vary from 1 to over 26lb (0.4 to 12kg).

General identification features include:

Materials and Appearance:

- Deployed above the surface.
- Light sheet-metal or plastic construction.
- Round or rectangle shaped body.
- Two-piece body with a seam at the junction.
- Legs or spike used to secure it in place.
- Tripwires.
- Means of manual arming.

Markings: Tan, brown, white, or green body with white or black markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: Command initiation with hand-compressed "clackers" or tripwires set for pull or tension release.

General Safety Precautions:

- HE, frag, B/T, movement.
- Safety precautions for fuze, if present.
- Treat all landmines as boobytrapped until conclusively proven otherwise.
- Do not cut tripwires until identity is confirmed.

Figure 10.7 Iranian copycat of the U.S. M18 Claymore mine. (Author's photograph.)

Figure 10.8 Russian MON100, front, side, and back views. Damage is from storage fire and explosions. (Author's photographs.)

2. Category: Landmine. Group: Anti-Tank (AT): Designed to explode with enough force to disable or destroy tanks and other large vehicles. Depending on configuration, explosive fillers range from little more than 1lb to over 25lb (0.5 to 11kg). Fuze settings and types vary, but usually require direct pressures of 150 to 400lb (68 to 181kg). Magnetic influence fuzing must be considered. When deployed, AT mines are usually protected by AP mines as a means of deterring clearance operations.

2.a. Category: Landmine. Group: AT-Blast: A non-fragmentation-producing mine designed to disable or destroy armored vehicles with explosive blast effects (Figure 10.9). Most designs are deployed just below the surface. When a vehicle drives over the mine, the explosive force follows the easiest path of resistance, upward into the vehicle, thus maximizing the energetic potential.

General identification features include:

Materials and Appearance:

- Deployed below the surface of the ground.
- Constructed of painted metal or colored plastic.
- Multi-piece construction.
- Have a primary fuze and multiple auxiliary fuze wells for boobytrapping.
- Means of manual arming.

Figure 10.9 Czech Republic PT-MI-BA-III, AT mine with a bakelite outer body. Note the fire and impact damage to the top of the mine, but the fuze remains intact and functional. (Author's photograph.)

Markings: Tan, brown, white, or green body with white or black markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: Direct pressure as primary fuzing. Boobytrap fuzing for secondary means of functioning. Self-destruct and anti-disturbance fuzing is included on some designs.

General Safety Precautions:

- HE, B/T, movement.
- Frag, for secondary frag from the environment.
- Safety precautions for fuze, if present.
- Treat all landmines as boobytrapped until conclusively proven otherwise.

2.b. Category: Landmine. Group: AT-EFP or Shaped-Charge: Contain a shaped charge or EFP to defeat armored and other hardened targets. Can be deployed above or below the surface (Figure 10.10) and function under a

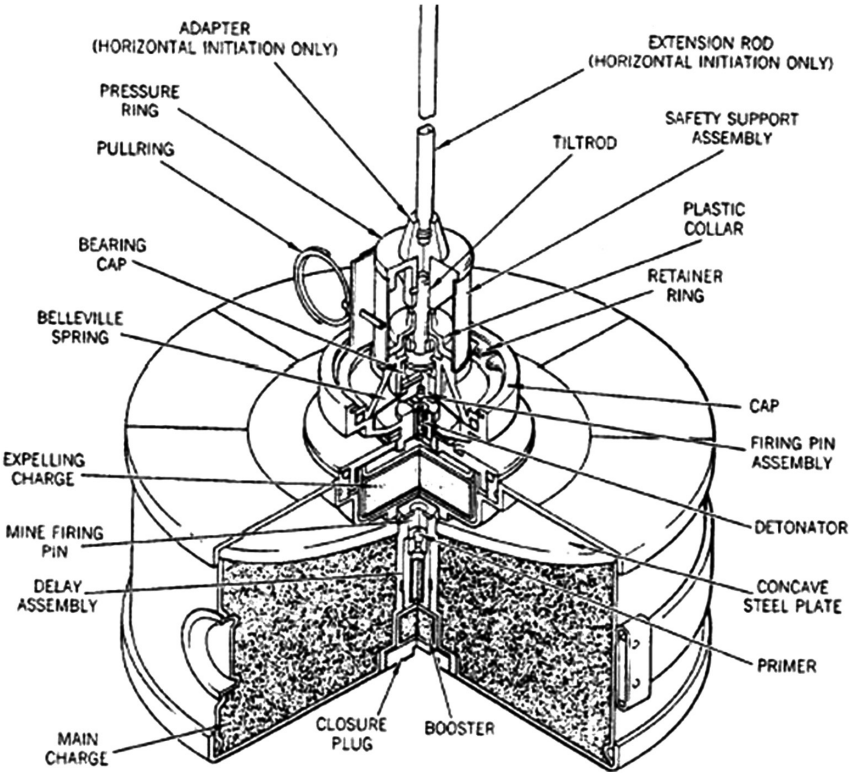

Figure 10.10 U.S. M21 AT mine incorporating an EFP. (From U.S. Military TM.)

vehicle via tilt-rod fuze. Or sit on the surface as the AT version of the FASCAM mentioned in the introduction. The BLU-91/B (Figure 10.11) has a magnetic influence fuze with an EFP capable of defeating the underside of a tank.

The AT version of the FASCAM mentioned in the introduction, including the air-dropped "Gator," artillery delivered "Remote Anti-Armor Munition" (RAAM), and helicopter delivered or ground-placed "Volcano" systems, will be used as an example as all three deploy the same munitions. The BLU-91/B is the AT-EFP-producing dispensed landmine used in conjunction with the BLU-92/B AP mine.

General identification features include:

Materials and Appearance:

- Deployed above or below the surface.
- Constructed of painted metal or colored plastic.
- Multi-piece construction.
- Have a primary fuze and multiple auxiliary fuze wells for boobytrapping.
- Primary fuze may have a tilt-rod.
- Means of manual arming.
- The lack of an external fuze suggests an internal influence fuzing.

Markings: Tan, brown, white, or green body with white or black markings are common. Dispensed mines may be unpainted. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: For conventional designs such as the M21 (Figure 10.10), an impact-initiated tilt-rod fuze will ensure an underbelly detonation. For sophisticated designs such as the BLU-91/B, a magnetic influence fuze protected by an internal anti-disturbance and low-voltage self-destruct feature may be present.

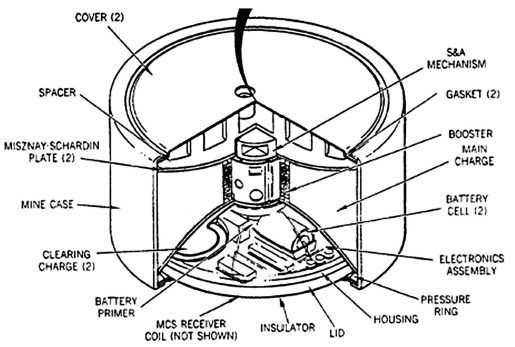

Figure 10.11 U.S. BLU-91/B, AT dispensed mine with magnetic influence fuzing. (From U.S. Military TM, and photograph courtesy of Dan Evers.)

General Safety Precautions:

- HE, frag, B/T, jet, movement.
- Safety precautions for fuze, if present.
- Treat all landmines as boobytrapped until conclusively proven otherwise.
- Do not cut tripwires until identity is confirmed.

3. Category: Landmine. Group: Practice: Designed to replicate live mines in size and shape; many designs contain robust explosive or spotting charges, while others are hollow versions of the live mine.

General identification features include:

Materials and Appearance:

- Construction features consistent with the landmine they are designed to imitate.

Markings: Blue, green, white, tan or brown, with white or black markings are common. May be unpainted or have brown markings for spotting charges. Other colors, stamped or stenciled marking, and symbols may also be present.

Common Fuze Configurations: If fuzed, the fuze will be the same type employed on the landmine being imitated.

General Safety Precautions:

- Movement.
- Observe all applicable safety precautions for the live landmine until positive identification is made.
- HE, frag, B/T, ejection when a spotting charge is present.
- Safety precautions for fuze, if present.
- Treat all landmines as boobytrapped until conclusively proven otherwise.
- Do not cut tripwires until identity is confirmed.
- Practice means practice, it does not mean inert.

Closing

Landmines, especially dispensed mines, may be difficult to recognize. However, they are inherently dangerous and designed to be initiated by their victim. As such, always consider a landmine to be in a hazardous condition until proven otherwise.

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Ordnance Group—Chemical

11

There's no sense to this objection. It is considered a legitimate mode of warfare to fill shells with molten metal which scatters upon the enemy and produces the most frightful modes of death. Why a poison vapor which kills men without suffering is to be considered illegitimate is incomprehensible to me. However, no doubt in time chemistry will be used to lessen the suffering of combatants.

Sir Lyon Playfair, 1854

Prelude

Many categories covered in earlier chapters have a "chemical group;" however, due to the unique threats associated with chemical munitions, they are afforded a separate chapter, rather than scattering them throughout previous chapters.

Munitions containing White Phosphorus (WP), burning smoke, riot control agents, and other fillers involving complex chemical compositions such as the Tri-Ethyl Aluminum (TEA) filled rocket (Figure 5.10, Chapter 5) are often classified under "chemical" ordnance. For the purpose of this text, "chemical ordnance" includes munitions containing a chemical substance designed to kill, injure, or incapacitate through physiological effects, such as nerve, blister, blood, choking, and incapacitating agents. For research purposes, search under "chemical" when having difficulty identifying an unknown munition.

Introduction

The wartime deployment of chemicals as weapons came a thousand years before the discovery of black powder. By the mid-1800s scientists were producing deadly chemical agents, and facing the same moral questions heard today. During the Crimean War, Sir Lyon Playfair requested permission to use cyanide-filled projectiles to break the siege of Sebastopol. The British War Office condemned the idea as "inhumane and as bad as poisoning the

enemy's water supply." Sir Playfair's response, at the beginning of this chapter, implied chemical weapons offered a painless death, which was not an accurate assessment (Figure 11.1).

The first multinational attempt to limit the use of chemical weapons took place at the Brussels Convention in 1874, followed by conventions in 1899 and 1907. Unfortunately, all three conferences resulted in weak, vaguely worded resolutions. As a result, WWI became a large-scale chemical weapons testing ground.

World War I

The tactical deployment of chemical weapons reached its operational peak during WWI. It began with a German attack near Ypres, Belgium, on April 15, 1915, when 150 tons of chlorine gas was released into a slight wind from 6,000 cylinders to blow across the battlefield. Though somewhat successful, this method of delivery and dissemination was crude and a wind-shift would push the cloud in the wrong direction.

Over the next two years, mustard, phosgene, and cyanide weapons were introduced, and better delivery and dissemination methods were developed. On July 12, 1917, a German artillery attack delivered mustard agent in a far more efficient manner, resulting in 20,000 allied casualties. The full potential of a deadly chemical agent efficiently delivered and disseminated in a manner to maximize its operational potential had been realized. Throughout the remaining years of WWI, just about every country involved deployed chemical munitions in massive numbers.

Figure 11.1 Person who came in contact with a Blister Agent in 2004. (DoD photograph.)

From World War I to Today

After WWI, the Geneva Convention of 1925 specifically addressed restricting the use of chemical weapons. As with previous conventions, there were many violations. In the late 1930s, Dr. Gerhard Schrader, a German industrial chemist, synthesized the first nerve agent, tabun (GA). Two years later, he synthesized sarin (GB), an even more toxic nerve agent. The bar for chemical agents, in terms of lethality, had risen.

Throughout WWII, with thousands of tons of chemical munitions in inventory, there were only a few chemical weapon deployments. After WWII, many countries continued chemical weapons programs. In 1993, the Chemical Weapons Convention Treaty was signed by 165 countries. The treaty prohibited manufacturing or stockpiling chemical weapons and many countries, including the United States and Russia, began destroying stockpiles.

The Variables Associated with Successful Deployment

Successful deployment of a chemical agent requires that a few variables be addressed. To be effective, a toxic material must be delivered in an appropriate concentration to provide the required dosage.

Form: Agents can be in solid, liquid, or gas form. The physical properties of an agent determine the best tactical means of disseminating it.

Concentration: Addresses the strength and persistence of an agent.

Dosage: The amount of agent a person takes in via inhalation, ingestion, contact with the skin, or a combination of two or all three.

Dissemination: Most chemical munitions use an explosive burster to break open the body and disperse the filler. All agents freeze and boil at different temperatures, react differently to precipitation, have different molecular weights, and are affected from high temperatures generated by burster detonation. They also spread differently depending on how wind speed, temperature, vertical temperature gradients (VTGs), precipitation, and topography affect the agent.

Time: Once disseminated, the dosage received by a person will be a result of concentration and time. The longer a person is exposed to an agent, the higher the dosage will be.

The Agents

Chemical agents are classified by the physiological effects they produce, and include nerve, blister, blood, choking, and incapacitating agents.

Nerve Agents: Affect the central nervous system and may be inhaled, ingested, or absorbed through the skin. The systemic effects of nerve agents

result when they inhibit cholinesterase, which hydrolyzes the neurotransmitter acetylcholine, resulting in an accumulation of acetylcholine in nerve junctions throughout the body. Symptoms include pinpoint pupils, difficulty breathing, confusion, twitching and jerking muscles, and convulsions.

Examples of nerve agents include:

- Nonpersistent agents: GA (tabun), GB (sarin), and GD (soman).
- Persistent agent: VX.

Blister Agents (vesicants): Originally developed during WWI, they burn and blister all parts of the body they contact, including skin and lungs if inhaled (Figure 11.1). Blister agents tend to be nonvolatile, presenting a greater contact threat than inhalation. Some of the most commonly encountered chemical munitions outside military control are WWI vintage projectiles filled with blister agents.

Examples of blister agents include:

- Sulfur mustards: H, HD, HT, HL, and HQ
- Nitrogen mustards: HN-1, HN-2, and HN-3
- Arsenicals L (Lewisite): ED, MD, PD
- Urticant: CX

Blood Agents: Interfere with oxygen utilization at the cellular level. The effect is somewhat similar to high levels of carbon monoxide exposure. These agents are highly volatile and dissipate quickly in outdoor environments. However, they work very well in enclosed space and AC is still used in gas chambers for capital punishment.

Examples of blood agents include:

- Hydrogen cyanide: AC, Zyklon-B
- Cyanogen chloride: CK

With an ability to quickly degrade gas mask filers, CK can be deployed prior to nerve agents with great effect.

Choking Agents: Cause severe lung damage, resulting in the lungs filling with fluid, referred to as "dry land drowning." Some agents are volatile and dissipate quickly, while others such as CG are heavier than air and can linger in low-lying areas for many hours under light wind conditions.

Examples of choking agents include:

- Chlorine: CL
- Phosgene: CG
- Chloropicrin: PS
- Diphosgene: DP

Military-Grade Incapacitating Agents: Riot control agents are often referred to as "incapacitating" agents as they may blur a person's vision and cause a burning sensation for a short time, though a person is not rendered fully incapacitated. On the other hand, military-grade incapacitating agents alter or disrupt the functions of the central nervous system (CNS) with hallucinogenic symptoms similar to LSD. Depending on dosage, a person can be fully incapacitated for hours or days.

Examples of known incapacitating agents include:

- 3-quinuclidinyl benzilate (QNB) (NATO name "BZ")
- d-lysergic acid diethylamide (LSD-25)
- Agent 15
- Kolokol-1
- Fentanyl and cannabinol derivatives

Ordnance Categories with a Chemical Group

When faced with a situation where chemical ordnance may be present, the first step in determining the group should be to rule out "chemical." An example of such a situation would be ordnance discovered in an oyster shell driveway in a mid-Atlantic state, and other locations where confirmed chemical munition recoveries have been made. Other more obvious areas include those near former Proving Grounds or battlefields where chemical munitions were tested or used. Over the previous hundred years, many chemical munitions were disposed of at sea. Today, these munitions are dredged up by ships or pushed onto beaches during storms.

Most chemical fillers used with ordnance have a thin liquid or thick jelly-like consistency. As such, chemical munitions are often configured similarly to munitions loaded with liquid or WP fillers. The most accurate means of differentiating a chemical munition are special features, color codes, and markings (Figures 11.2 through 11.4). When inspecting an old, damaged, or repainted munition in which "chemical" cannot be ruled out as a possibility, assume the munition may contain a chemical filler until proven otherwise.

Inspection: When inspecting a possible chemical munition, apply the Seven-Step Practical Process from the relevant ordnance category or chapter. X-ray is a viable tool for inspecting ordnance from most categories and groups, but for suspected chemical munitions, a portable x-ray unit, if available, should be the first-choice tool selection. Prior to shooting an x-ray, tilt the munition as seen in Figure 11.2. Two consistent aspects of chemical munitions: they are filled with pliable materials and are not completely full. Ordnance must be able to endure intense heat as well as subzero temperatures and still function correctly. Due to normal expansion and contraction

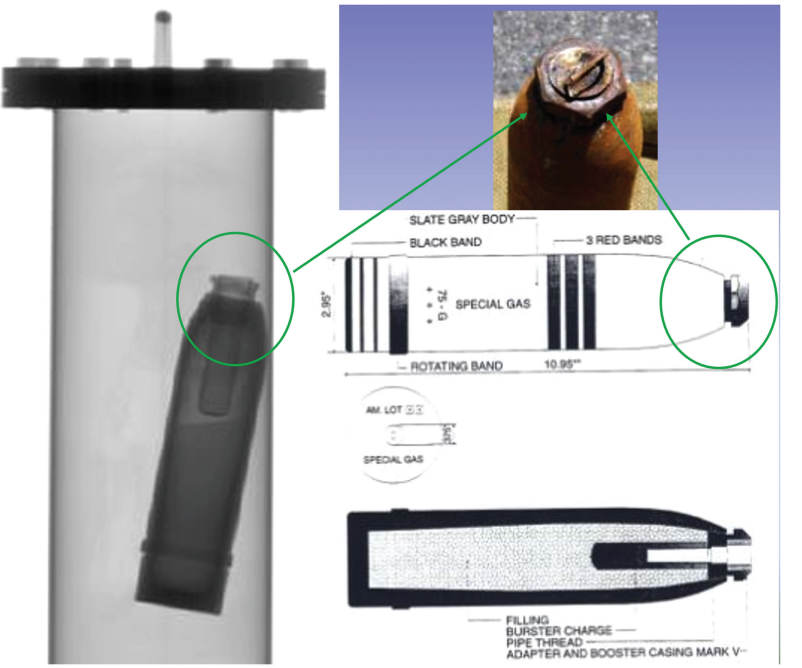

Figure 11.2 Left: X-ray of a U.S. 75mm, WWI-era chemical projectile in a HAZMAT container. Right: Note the unique shape of the fuze burster-adapter (circled), which is specific to early U.S and French 75mm chemical projectiles. Over the last ten years, 24 of these projectiles have been recovered in Delaware. (Courtesy of the Delaware State Police Bomb Squad.)

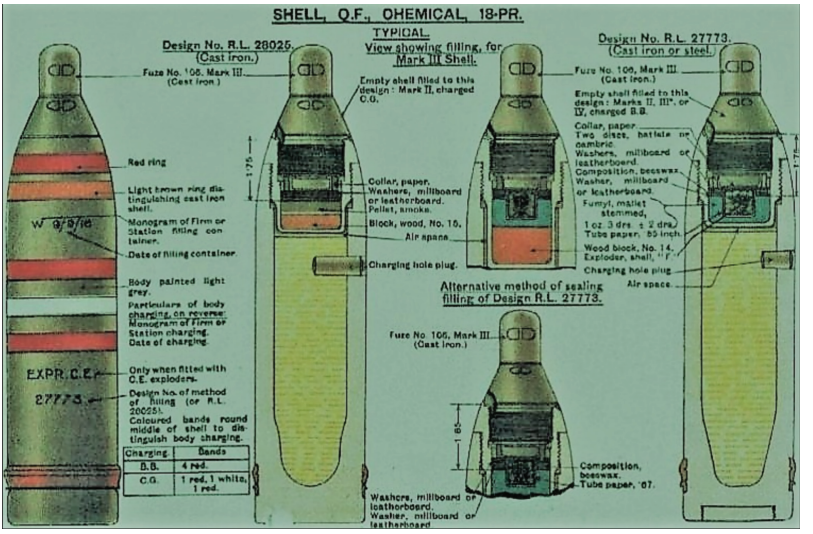
SHELL, Q.F., CHEMICAL, 18-PR.
TYPICAL
View showing filling, for Mark III Shell.
Design No. R.L. 28025. (Cast iron.)
Design No. R.L. 27773. (Cast iron or steel.)
Fuze No. 106, Mark III. (Cast iron.)
Empty shell filled to this design: Mark II, charged C.G.
Red ring
Light brown ring distinguishing cast iron shell.
Monogram of Firm or Station filling container.
Date of filling container.
Body painted light grey.
Particulars of body charging, on reverse: Monogram of Firm or Station charging. Date of charging.
Only when filled with C.E. exploders.
Design No. of method of filling (or R.L. 28025).
Coloured bands round middle of shell to distinguish body charging.
Charging | Bands
B.B. | 4 red.
C.G. | 1 red, 1 white, 1 red.
Collar, paper.
Washers, millboard or leatherboard.
Pellet, smoke.
Block, wood, No. 16.
Air space.
Charging hole plug.
Alternative method of sealing filling of Design R.L. 27773.
Fuze No. 106, Mark III. (Cast iron.)
Composition, beeswax.
Tube paper, '07.
Washers, millboard or leatherboard.
Washer, millboard or leatherboard.
Empty shell filled to this design: Marks II, III*, or IV, charged B.B.
Collar, paper.
Two discs, battale or oambric.
Washers, millboard or leatherboard.
Composition, beeswax.
Washer, millboard or leatherboard.
Fumyt, millet stemmed,
1 oz. 3 drs ± 2 drs.
Tube paper, 55 inch.
Wood block, No. 14.
Exploder, shell, "F"
Charging hole plug.
Air space.

Figure 11.3 British 18-pounder (8.16kg) chemical projectile. Note the unique filler-hole on the side of the projectile. (From U.S. Military Technical Paper.)

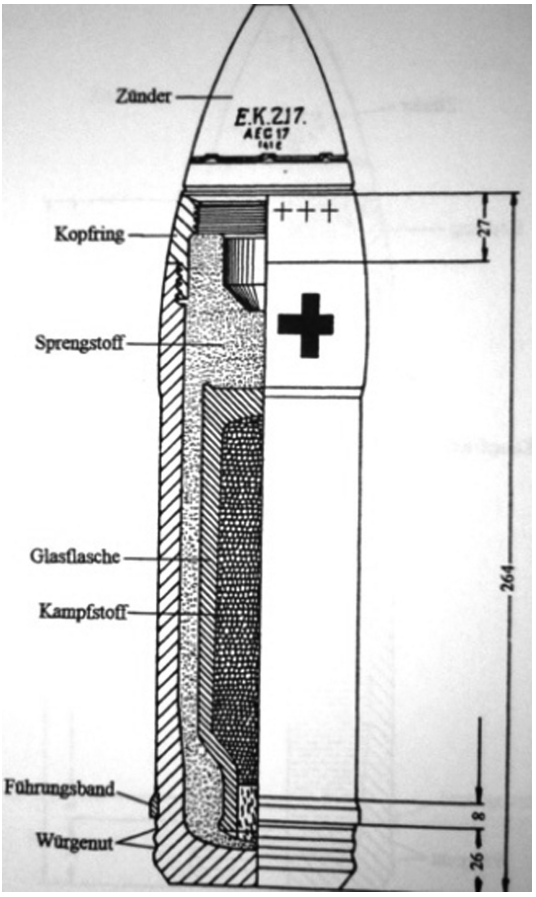

Figure 11.4 German WWI-era chemical projectile. Translated: Sprengstoff = Explosive, Glasflasche = Glass (bottle), Kampfstoff = Chemical Agent, and Kopfring = Stop Ring (adapter). (From U.S. Military TM.)

caused by temperature changes, chemical munitions are filled to approximately 75% of full capacity. By tilting the munition, the unnatural line where the chemical filler stops can be visualized.

There are binary nerve agent projectiles containing two containers, separated by a blow-out disk. The disk is designed to break when the projectile is fired, allowing components to mix during flight. When inspected via x-ray, the configuration is different from a conventional chemical munition design. But with both components in liquid form, the unnatural line(s) can still be seen.

Chemical ordnance is presented below in category or chapter order; projectiles, rockets, guided missiles, bombs, submunitions, and landmines. See Appendices D and E for information on marking schemes.

1. Category: Projectile. Group: Chemical: Common configurations involve a chemical agent sealed in the projectile with a burster adapter

containing a high-explosive. In literature from the WWI-era, burster chargers are often referred to as a "gaine" which served the same purpose. Upon fuze functioning, the burster or gaine detonates, breaking the projectile body into a few large pieces while dispersing the chemical agent.

General identification features include:

Materials and Appearance:

- Solid, one-piece body of robust construction.
- Burster adapter that seals in the chemical filler, located between the ogive and fuze.
- Lead washers were often used to seal fuze, burster, and projectile body connections.
- The adapter booster may have wrench flats or spanner holes.
- Rotating band or gas-check bands.
- A flush solid base.
- If a tail boom or fins are present, there will not be a venturi consistent with a rocket or an open tube opening consistent with a rifle grenade at the base.

Markings: Gray body with yellow, green, or red markings are common. Purple was used by NATO to identify incapacitating agents. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configuration: PD fuzing on older projectiles. MT or ET fuzing is feasible on newer projectiles.

General Safety Precautions:

- HE, frag, movement, chemical.
- Safety precautions for fuze, if present.

2. Category: Rocket. Group: Chemical: Common configurations involve a chemical agent sealed in the warhead with a burster adapter containing a high-explosive burster extending from the fuze well down the center of the warhead. Upon fuze functioning, the burster breaks the warhead into a few large pieces while dispersing the chemical agent.

General identification features include:

Materials and Appearance:

- Solid, one-piece body of robust construction.
- Burster adapter between the ogive and fuze, which seals in the chemical filler.
- The adapter booster may have wrench flats or spanner holes.

- A flush solid base and a means of attaching to a motor.
- Fin assembly on the aft end of the motor.
- One or more venturis on the base of the motor.

Markings: Gray body with yellow, green, or red markings are common. Purple was used by NATO to identify incapacitating agents. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configuration: PD and VT fuzing is most feasible.

General Safety Precautions:

- HE, frag, movement, chemical for warhead and motor.
- Ejection, EMR, static for unfired motor.
- Safety precautions for fuze, if present.

3. Category: Missile. Group: Chemical: Missiles designed to deploy chemical agents tend to be of considerable size, such as the SA-2 in Figure 7.7 in Chapter 7.

General identification features include:

Materials and Appearance:

- Multi-piece construction.
- Made with high quality materials and machining.
- Fin configurations with movable surfaces.
- A motor on the aft end, and possibly a second mid-body.
- A nose-cone or cap made of glass or plastic.
- Guidance components, wire spools or glass on the base.
- If warhead is visible, a burster adapter between the ogive and fuze, which seals in the chemical filler.

Markings: Gray body with yellow, green, or red markings are common. Purple was used by NATO to identify incapacitating agents. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configuration: S&A device with impact and VT capability is most feasible.

General Safety Precautions:

- HE, frag, movement, chemical for warhead and motor.
- Ejection, EMR, static for unfired motor.
- Safety precautions for fuze, if present.

4. Category: Bomb. Group: Chemical: Many countries design and manufacture chemical-specific bombs, such as the U.S. MK116 Weteye bomb

containing 350lb (160kg) of sarin. However, most chemical bombs are made by slightly modifying bomb bodies, modifications that may be difficult to detect (Figures 11.5 and 8.7 in Chapter 8).

General identification features include:

Materials and Appearance:

- Vary greatly depending on design.
- Body of lightweight material or modified HE bomb.
- Conventional or strap-lug configuration (Figure 11.5).
- Old, box fin, or conventional low-drag fin designs.

Markings: Gray body with yellow, green, or red markings are common. Purple was used by NATO to identify incapacitating agents. Data plates may be present on the base. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configuration: PD and VT fuzing.

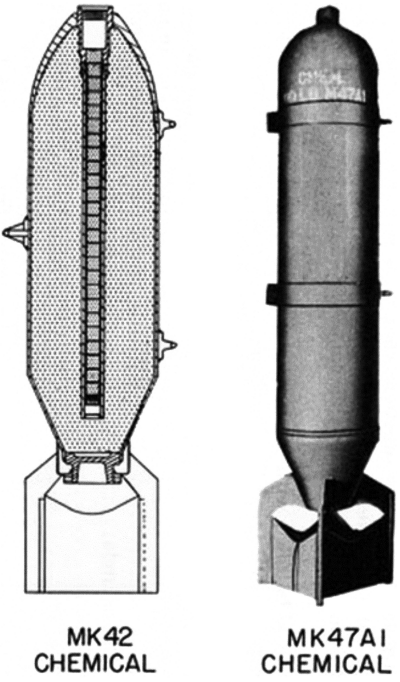

Figure 11.5 U.S. 100lb (45.36kg) chemical bombs. (From U.S. Military TM.)

General Safety Precautions:

- HE, frag, movement, chemical.
- Safety precautions for fuze, if present.

5. Category: Submunition. Group: Chemical: Many submunitions ignore conventional color-coding schemes, making positive identification more difficult.

General identification features include:

Materials and Appearance:

- Light, thin-skin metal body (Figure 11.6).
- Multi-piece construction.

Markings: Gray body with yellow, green, or red markings are common. Colors or marking may be absent. Purple was used by NATO to identify incapacitating agents. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configuration: All-ways-acting impact fuzing.

General Safety Precautions:

- HE, frag, movement, chemical.
- Safety precautions for fuze, if present.

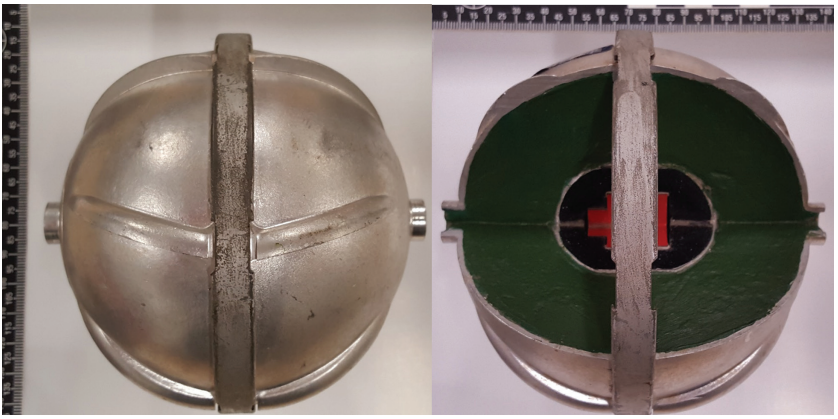

Figure 11.6 U.S. M139 chemical submunition containing 1.3lb (590gr) GB-sarin nerve agent dispersed by an all-ways-acting fuze and burster. Practice versions may contain a live fuze and burster without the chemical filler. (Author's photograph.)

6. Category: Landmine. Group: Chemical: Most chemical landmines are slightly modified Anti-Tank (AT) or Anti-personnel (APERS) landmines, modifications that may be difficult to detect. For example, the M23 VX landmine in Figure 11.7 has four raised projections not found on the original M15 AT design.

General identification features include:

Materials and Appearance:

- Deployed below the surface of the ground.
- Constructed of painted metal or colored plastic.
- Multi-piece construction.
- Have a primary fuze and multiple auxiliary fuze wells for boobytrapping.
- Means of manual arming.

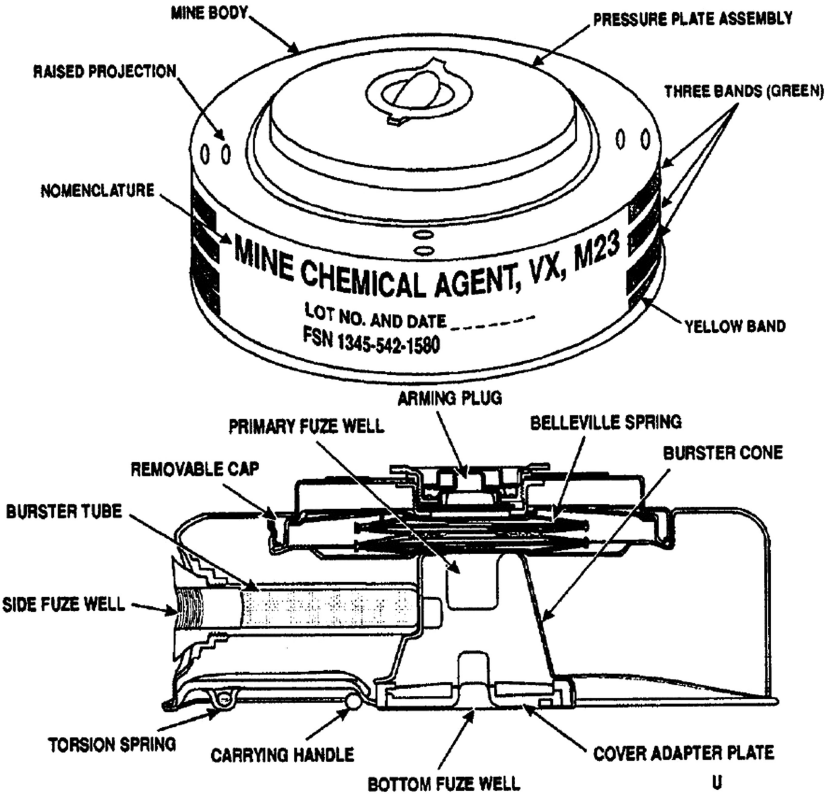

Figure 11.7 Line drawing of an M23, which contains over 10lb (4.5kg) of VX dispersed by a 14oz (397gr) burster. (From U.S. Military TM.)

Markings: Gray body with yellow, green, or red markings are common. Purple was used by NATO to identify incapacitating agents. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: Direct pressure as primary fuzing. Boobytrap fuzing for secondary means of functioning.

General Safety Precautions:

- HE, frag, B/T, movement, chemical.
- Safety precautions for fuze, if present.
- Treat all landmines as boobytrapped until conclusively proven otherwise.

Closing

The injuries seen in Figure 11.1 resulted from a 100-year-old, WWI munition. Chemical munitions pose significant short- and long-term threats and are best avoided through accurate and timely identification. When inspecting an unknown munition, consider a possible chemical filler until proven otherwise.

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Ordnance Category—Underwater Ordnance 12

Damn the torpedoes, full speed ahead.
Admiral David Farragut, Battle of Mobile Bay, August 5, 1864

Introduction

The majority of underwater ordnance is designed to influence shipping by denying access or destroying an enemy's ships. During the U.S. Civil War, Confederate forces did this by deploying "torpedoes" configured in such a way to be described as moored mines today. When the battle for Mobile Bay began in August of 1864, Union forces navigating a complex minefield lost the monitor *USS Tecumseh* when it struck a torpedo and immediately sank. For a moment, it appeared as if the minefield would achieve its objective of denying the Union flotilla access to Mobile Bay. But Admiral Farragut's orders led Union forces through the minefield.

Some accounts have the Admiral's actual words as "Damn the torpedoes! Four bells! Captain Drayton, go ahead! Jouett, full speed!" But the "Damn the torpedoes…" quote certainly captures the intent as additional ships were lost while sailors heard torpedoes bang and scrape along ships' hulls. The fact that many of these torpedoes did not explode alludes to technical shortfalls in the fuzing configurations, a problem not often seen today.

Operating in an underwater environment is extremely different from land-based operations, which is reflected in the designs of these munitions. In fact, designs are so different that in the United States, Navy EOD technicians attend an additional two months of training focused solely on this ordnance category.

However, with thousands of incidents each year involving these munitions being encountered inland, washing up on beaches, or pulled up by fishing vessels, it is imperative that one have a fundamental understanding of what they are and how they work. Beach recoveries, especially after a storm are a daily occurrence in the U.S. Where incidents such as the *Trawler Snoopy*, destroyed when the German WWII torpedo they pulled up, detonated; or the 70ft (21.3m) fishing boat *Shinnecock I* that pulled up a 1,200lb (544kg) torpedo, later detonated by the U.S. military, are less common, but usually catastrophic.

Underwater munitions are designed to damage, disable, or sink ships; target combat swimmers; mark targets, determine wind speed or direction; and a host of other tasks. See Appendices D and E for information on marking schemes.

Seven-Step Practical Process and Underwater Ordnance

Examples of different designs, features, color codes, markings, and construction features are provided throughout this chapter.

Step 1: Gather Information, Approach, and Initial Inspection: Attempt to identify from a safe distance with binoculars. Approach at a 45° angle from the rear, avoiding ejection ports, propellers, and fuze sensing elements.

With sketch pad and camera, document identifying features including fins, horns, influence sensors, propellers, motors, leaking material, color codes, stamped markings, construction features, damage, signs of tampering or modification. Also note and measure the width and length of each component.

Some underwater ordnance will have detailed information stamped into the body; including the model, weight, and type of explosive, date of manufacture, and a shipping address. If not, the three fastest means of researching an unknown underwater munition are:

1. Overall diameter and length
2. Overall shape and external protrusions
3. If present, the number and type of propellers and fins

Step 2: Determine Fuze/Exploder Type and Condition:

Some underwater ordnance uses the term "exploder" versus "fuze" to describe a fuzing system.

If recovered in or near water, or shows other signs associated with deployment (step 5), the fuze-exploder is considered armed. If the fuze-exploder is damaged, pins have been removed, or alterations have been made, it is considered armed. If visible, measurements for the fuze-exploder are taken separately from the munition.

Step 3: Determine Ordnance Category:

Ordnance designed to be deployed underwater is covered throughout this chapter.

Step 4: Determine Ordnance Group:

The identifiable characteristics associated with each underwater ordnance category and group are covered throughout this chapter.

Step 5: Determine if Munition was Deployed:

Inspect for impact-related damage, fired motors, missing pins or clips; if found in or near water, assume the munition was deployed.

Step 6: Determine Safety Precautions:

Safety precautions for each group are covered in this chapter. Once identified, these precautions must be adhered to.

Step 7: Research Literature and Identify the Munition:

Apply the totality of measurements, color codes, stamped markings, and construction features to determine the group, and positively identify the munition and possible fuzing configuration.

Groups

A basic definition of underwater ordnance is a munition designed to be deployed in water. It does not apply to other ordnance categories dumped or fired into water environments.

In order to provide a congruent flow, underwater ordnance is divided into the following primary and supplemental groups:

1. Torpedo
2. Depth bomb
3. Depth charge
4. Hedgehog
5. Mines
   a. Moored
   b. Bottom
   c. Limpet
   d. Shallow water
6. Sound signal
7. Pyrotechnic marker

1. Category: Underwater. Group: Torpedo: Self-propelled weapons designed to sink surface ships and submarines with a high explosive warhead ranging from 100 to over 800lb (45 to 362kg). Torpedoes can be tube-fired from ships and submarines or dropped from aircraft. Once deployed, they can be tracked to the target via wire guidance or use active and passive acoustic homing. Historical information on the naming and tactical development of torpedoes is covered in Chapter 13.

General identification features include (Figure 12.1).:

Materials and Appearance:

- Multi-piece construction.
- Made with high quality materials and machining.
- Over 20in (50.8cm) diameter (U.S. torpedoes are 21in.).
- May be over 20ft (6.1m) in length.

- May have one or more screws (propellers) on aft end.
- Vertical fins toward the aft end with movable surfaces for direction changes.
- A shroud encircling fins to protect the screws.
- If wire guided, wire possibly attached at the aft end.
- If deployed from aircraft, lugs or cleats may be present.

Markings: Gray and black bodies with yellow, white, or black markings are common. A brown band may be present on the motor. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze-Exploder Configurations: Impact, magnetic and acoustic influence, active and passive homing is common. Torpedo fuzing locations include the nose, side (transverse), or inside covered by the outer skin.

General Safety Precautions:

- HE, frag, movement for the warhead and motor.
- Ejection, EMR, static for unfired motor, ejection ports, high-voltage and high-pressure components and explosive actuators.
- Chemical, if guidance section or motor is damaged or leaking.
- Do not remove encrusted marine growth.
- Safety precautions for fuze-exploder, if present.

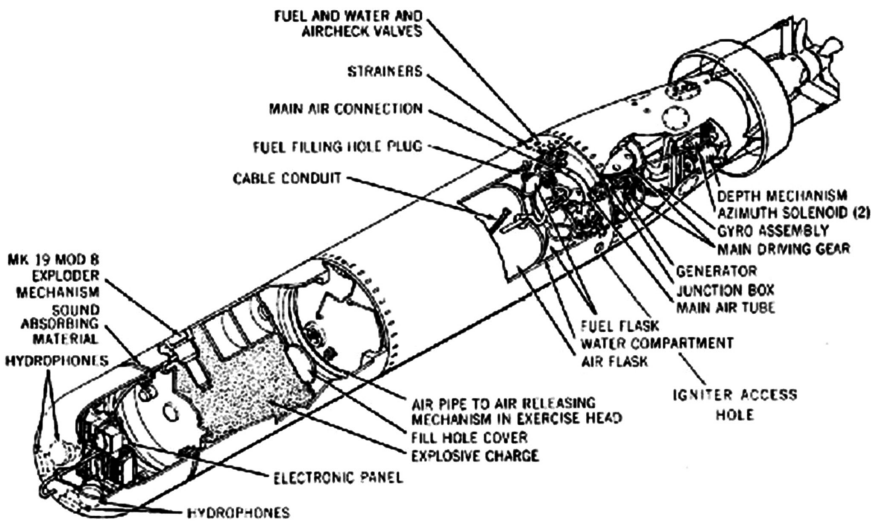

Figure 12.1 There are hundreds of different torpedo designs; this is an example of a common configuration. (From U.S. Military TM.)

2. Category: Underwater. Group: Depth Bomb: Designed to destroy submarines and other submerged targets with a high-explosive main charge ranging from 100 to over 300lb (45.4 to 136kg). Dropped from aircraft the same way as an air-dropped bomb, they can also be deployed against land targets.

General identification features include (Figure 12.2):

Materials and Appearance:

- Heavy duty one-piece body construction.
- Fins or other means of orientation.
- Lugs or cleats to fix to an aircraft.

Markings: Gray and black bodies with yellow, white, or black markings are common. A brown band may be present on the motor. Stamped or stenciled markings may be present between the lugs or cleats.

Common Fuze-Exploder Configuration: Hydrostatic pressure or impact fuzing for waterborne deployment, impact for use against land-based targets. Fuze wells in the nose, tail, or side (transverse), some designs have all three.

General Safety Precautions:

- HE, frag, movement.
- Do not remove encrusted marine growth.
- Safety precautions for fuze-exploder, if present.

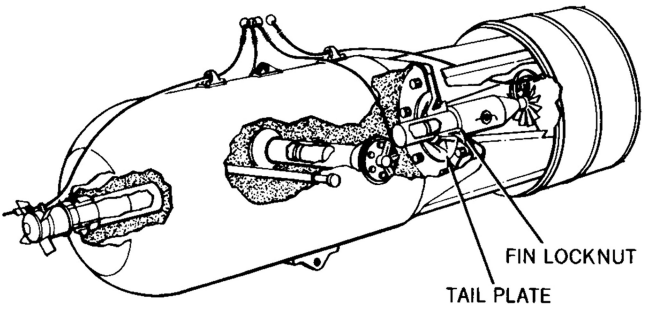

Figure 12.2 U.S. depth bomb with nose, tail, and transverse fuzing. (From U.S. Military TM.)

3. Category: Underwater. Group: Depth Charge: Deployed from ships by sliding down rails or projected by special launch platforms to destroy submarines.

Smaller, hand-deployed depth charges are used for other submerged targets such as combat swimmers. Due to the large variations in size, high-explosive main charges vary from 3 to 300lb (1.36 to 136kg).

General identification features include (Figure 12.3):

Materials and Appearance:

- Heavy duty one-piece body construction.
- Fins on some designs.

Markings: Gray and black bodies with yellow, white, or black markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze-Exploder Configurations:

- Ship Launched: Hydrostatic arming-functioning. May have influence or impact fuzing. Fuzing-exploder locations include the nose, tail, and side (transverse).
- Hand Deployed: Direct armed—hydrostatically functioned at a preset depth.

General Safety Precautions:

- HE, frag, movement.
- Do not remove encrusted marine growth.
- Safety precautions for fuze-exploder, if present.

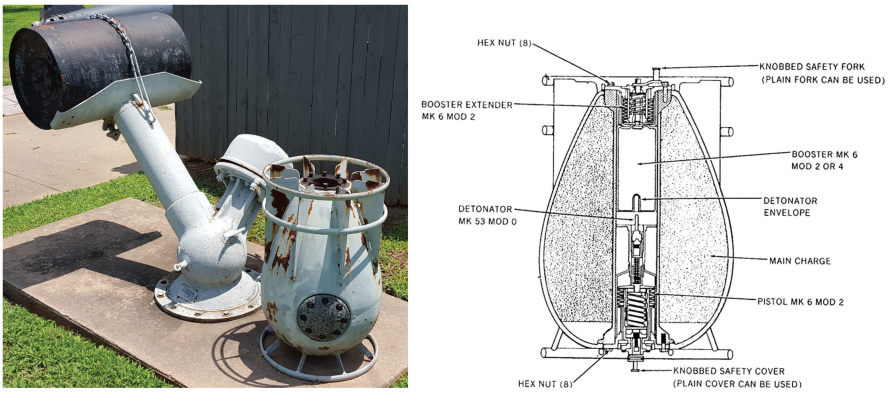

Figure 12.3 U.S. Depth Charges, left to right: MK-6 on a K-gun mount, with a MK-9 to the right, and a line drawing of a MK-9 MOD 4. The MK-9 MOD4, contains a 200lb (91kg) main charge and 40lb (18kg) of lead to increase its rate of descent. (From U.S. Military TM and author's photograph.)

4. Category: Underwater. Group: Hedgehog: A short-range rocket fired off the front of a ship, one at a time, or in salvos of up to 24 at a time, to destroy submarines and other submerged targets. Usually deployed in conjunction with depth charges, the high-explosive main charge for hedgehogs ranges from 36 to 200lb (16 to 90kg).

General identification features include (Figure 12.4):

Materials and Appearance:

- Warhead of heavy duty, one-piece construction.
- A cylindrical or teardrop shape with a flat ogive.
- Fuze well in the nose.
- Fin assembly on the aft end of the motor.
- One or more venturis on the base of the motor.

Markings: Green or gray body with yellow or black markings are common on warheads. A brown band may be present on the motor. Warhead

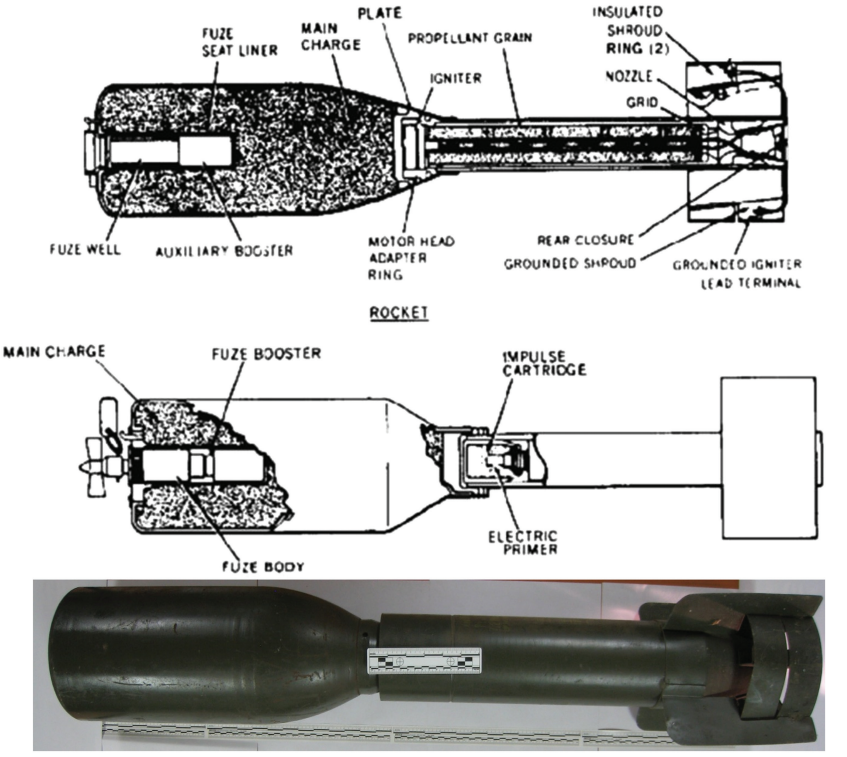

Figure 12.4 Top and middle: The internal configuration of the 7.2in (183mm) MK10 and MK11 Hedgehogs. (From U.S. Military TM). Bottom: The Army made a ground-based platform and designated these the "T-37 Demolition Rocket for ground-based deployment." (Author's photograph.)

and motor colors may match or be completely different. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze-Exploder Configurations: Hydrostatic arming-functioning for preset depths. May also have impact or influence fuzing.

General Safety Precautions:

- HE, frag, movement for the warhead and motor.
- Ejection, EMR, static for unfired motor.
- Do not remove encrusted marine growth.
- Safety precautions for fuze-exploder, if present.

5. Category: Underwater. Group: Mines: As with landmines (Chapter 10), underwater mines are specifically designed to be functioned by the intended victim and are always considered to be boobytrapped. They also present problems when hostilities end as poor record keeping and the underwater environment make locating some mines very difficult, resulting in hundreds-of-thousands of intact mines littering sea floors, lakes, harbors, rivers, and other waterways. For example, in 2009 a NATO naval demining exercise off Estonia was delayed by the discovery of 64 underwater mines from WWI and WWII. Since 1994, over 600 mines have been located in this small section of the Baltic Sea off the Estonian, Latvian, and Lithuanian coasts.

Due to the diversity associated with underwater mines, the group has been further broken down to cover; moored, bottom, limpet, and shallow-water mines.

5.a. Category: Underwater. Group: Moored and Drifting Mines: Most commonly deployed from ships with a cart that acts as an anchor; they are designed to explode with enough force to disable or destroy ships and submarines. Most configurations have explosive fillers of about 200lb (90kg) as a large portion of the mine is empty to keep it buoyant for proper deployment. Moored mines are designed to remain anchored in place (Figure 12.5), whereas drifting mines are equipped with a lighter anchor to fix it at a certain depth, while allowing it to drift with the current. Both moored and drifting mines employ similar fuzing with similar effects.

Both moored and drifting mines can have a chain or cable break, detach from the mooring anchor, and float on the surface. This circumstance can result in mines threatening unintended shipping lanes. To address this possibility, many designs include a flooder assembly and sterilizer (Figure 12.6) to sink or render the mine inoperable.

General identification features include:

Materials and Appearance:

- Heavy duty, steel body with access ports.
- Round, oval, or cylindrically shaped.

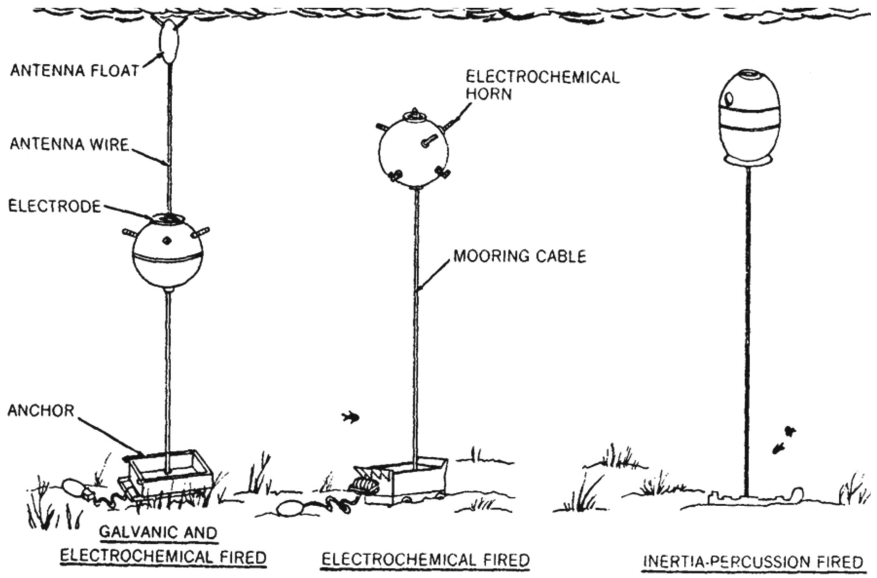

Figure 12.5 Depiction of three moored mine deployment variations. All are anchored to the sea floor, some deploy antenna. In this configuration, the antenna is used to increase vertical contact area of the mine. (From U.S. Military TM.)

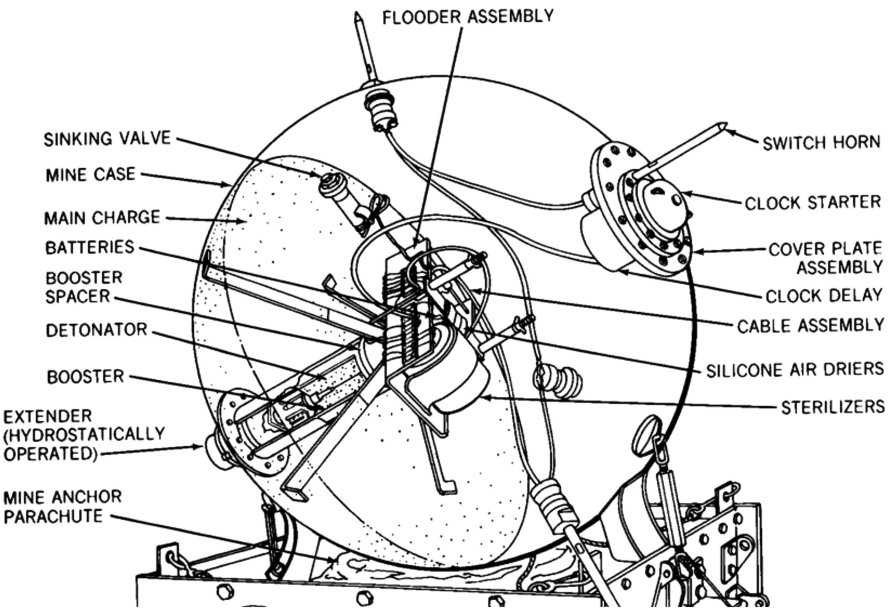

Figure 12.6 Internal configuration of a moored mine on the cart that will act as its anchor. (From U.S. Military TM.)

- 3 to 4ft (1m) in diameter.
- "Horns" protruding between 4 and 10in.
- May have mooring chain or cable attached to base.

Markings: Black or gray body with yellow or black markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze-Exploder Configurations:

- Impact fuzing incorporating chemical horns, switch horns and antennas (Figure 12.5).
- Internal flooder assembly and sterilizers (Figure 12.6) designed to sink or render a mine inoperable may also be present.
- May have hydrostatic arming for preset depths.

General Safety Precautions:

- HE, frag, B/T, movement.
- Ejection for undeployed sensors.
- Do not remove encrusted marine growth.
- Safety precautions for fuze-exploder, if present.

5.b. Category: Underwater. Group: Bottom Mines: As the name implies, bottom mines are deployed from ships, submarines, and aircraft, sink to and remain on the bottom until functioning (Figure 12.7).

While these mines are designed to destroy submarines by producing enough explosive force to crush the hull, different tactics are applied when targeting surface ships. For this, bottom mines explode as a ship passes over it to produce the

Figure 12.7 MK 52 bottom mine, incorporating a 1-hour to 90-day arming delay, 30-count ship counter, explosive sterilizer, and a hydrostatic arming device. Contains 625lb (283kg) of HBX-1, fuzing can include pressure, acoustic, or magnetic firing mechanisms. (Photograph courtesy of Tom Conte, USN Ret.)

initial shock front, which impacts the ship. However, the underwater explosion also produces a large bubble that grows in size as it rises in accordance with Boyle's law. The ship then drops into the void caused by the air-bubble, breaking the beam, resulting in catastrophic failure and rapid sinking.

With high-explosive main charges often exceeding 1,000lb (450kg), the air-bubble initially produced is large, but upon reaching the surface it is massive. The sudden shift in support along the main axis, or keel of the ship, literally snaps the hull.

General identification features include:

Materials and Appearance:

- May have dome, oval, or cylindrical shape; or have a camouflaged appearance to look like a rock or other natural underwater feature.
- Cylindrical shaped mines are large, averaging 20in (51cm) in diameter and over 71in. (180cm) in length.
- Dome-shaped mines are large, averaging 48in. (122cm) in diameter.
- Lugs or cleats if deployed from aircraft (Figure 12.7).

Markings: Black or gray body with yellow or black markings are common, as are camouflage colors and materials. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze-Exploder Configurations:

Transverse magnetic and acoustic fuzing, incorporating ship counters. Fuze-arming delay mechanisms ranging from one hour to many months, clockwork mechanisms, hydrostatic arming devices, and flooder or sterilizer assemblies designed to render a mine inoperable may all be present.

General Safety Precautions:

- HE, frag, B/T, movement.
- Ejection for undeployed sensors.
- Do not remove encrusted marine growth.
- Safety precautions for fuze-exploder, if present.

5.c. Category: Underwater. Group: Limpet Mines: The name "limpet" originates from the resemblance of these mines to the shell of a mollusk. Limpets are small mines, designed to be placed on ships below the waterline by combat swimmers, and appear as part of the ship (Figure 12.8).

Secured in place with strong magnets, epoxy, or suction cups, they contain high-explosive main charges of 2 to 5lb (0.9 to 2.3kg). Though the main

Figure 12.8 U.S. limpet mine. The Mechanical Time fuze threads into the protrusion on the far side. The anti-withdrawal device is armed by pulling the ring at the bottom. (Author's photograph.)

charges are small, the environmental factor of using a body-of-water to tamp the charge, maximizes the effects to ensure a breach of the ships side or bottom. Placement is also important and limpet mines are tactically placed near critical areas of a ship to damage, disable, or sink the vessel.

General identification features include:

Materials and Appearance:

- May have dome, oval, or cylindrical shape, with a flat side that goes against the ship.
- Diameters, lengths, and thicknesses vary greatly, but average 12 to 18in. (340 to 457mm) in diameter or length.
- Magnets, suction cups, or other means of affixing to a target.
- Steel or aluminum body.
- May have an outer plastic-like material for concealment.

Markings: Black, gray, green, blue, and other body colors with no external markings are common, as are camouflage colors and materials. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze-Exploder Configurations: MT for primary fuzing, and an anti-lift or anti-withdrawal device that is armed after mine placement is common.

General Safety Precautions:

- HE, frag, B/T, movement.
- Do not remove encrusted marine growth.
- Safety precautions for fuze-exploder, if present.

5.d. Category: Underwater. Group: Shallow-Water Mines: Specifically designed for deployment in the shallow waters of rivers and swamps, as well as the surf zone of lakes, seas, and oceans. Early configurations consisted of anti-tank (AT) mines weighted down or anchored with stakes, but the especially inhospitable environment of surf zones and swift river currents resulted in fuzing malfunctions or mines being swept away. As such, the mines made to operate in these environments have atypical shapes configured to survive and function effectively in these harsh environments (Figure 12.9).

Containing high-explosive main charges of 5 to 30lb (2.3 to 13.6kg), shallow-water mines can target landing craft and small boats operating in waters less than 20ft (6m) in depth.

General identification features include:

Materials and Appearance:

- Constructed of painted metal or colored plastic.
- Holes, threaded adapters, or other means of anchoring the mine in place.
- May have an outer plastic-like material for concealment.
- Multi-piece construction.
- Have a primary fuze and multiple auxiliary fuze wells for boobytrapping.
- Means of manual arming.

Figure 12.9 Three different configurations of shallow water mines. (Author's photograph.)

Markings: Black or green body with yellow or black markings are common, as are camouflage colors and materials. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: Direct pressure as primary fuzing. Boobytrap fuzing for secondary means of functioning. Self-destruct and anti-disturbance fuzing is included on some designs.

General Safety Precautions:

- HE, frag, B/T, movement.
- Do not remove encrusted marine growth.
- Safety precautions for fuze, if present.

6. Category: Underwater. Group: Sound Signals: Though these are not always found in ordnance publications, Sound Underwater Signals (SUS) and Sound Fixing and Ranging (SOFAR) devices have fuzing configurations and are deployed in the same manner as many ordnance groups. For this reason, they are included in this text.

SUS and SOFARs can be deployed from aircraft, ships, or submarines. Contain high-explosive main charges ranging from 0.25 to over 8lb (0.11 to 3.7kg), they are used for signaling, calibrating oceanographic equipment, locating submarines and other submerged objects by tracking reflected sound waves Figure 12.10).

General identification features include:

Materials and Appearance:

- Multi-piece construction.
- Made of steel or aluminum.
- Usually between 14 and 22in. (355mm and 559mm) in length.
- Usually between 2 to 3in (51 to 76mm) in diameter.
- May have fins on the aft end.

Markings: Colors inconsistent with recognized ordnance markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: Hydrostatic arming and functioning, preset for specific depth. Some fuzes (Figure 12.10) incorporate a cocked firing pin, or Cocked Striker (C/S).

General Safety Precautions:

- HE, frag, movement.
- Do not remove encrusted marine growth.
- Safety precautions for fuze, if present.

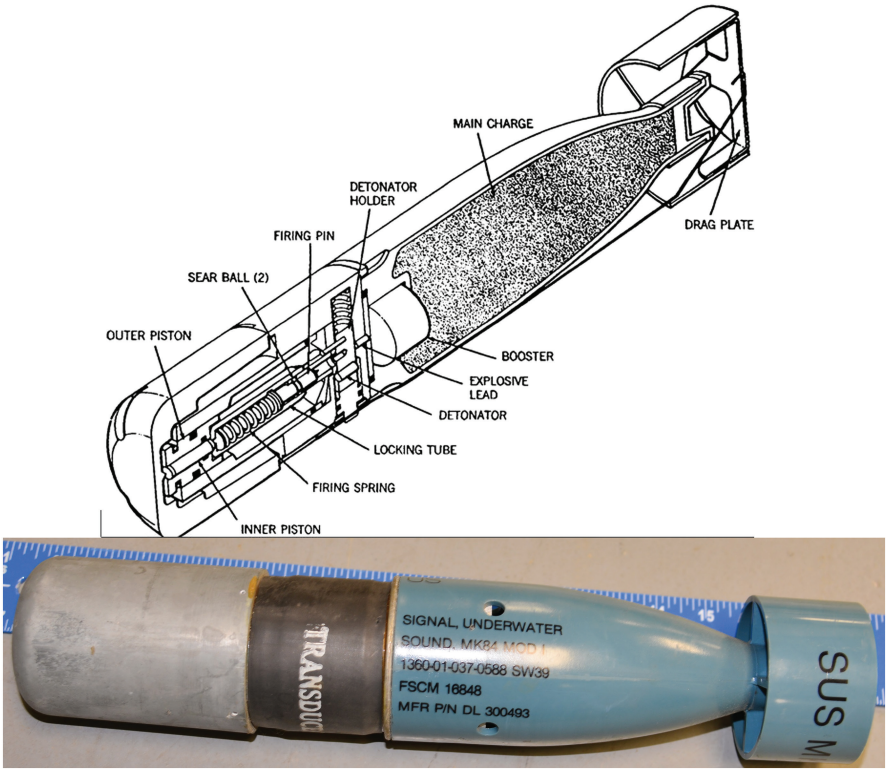

Figure 12.10 Top: Internal configuration of a Sound Underwater Signal (SUS) device. (From U.S. Military TM). Bottom: MK-84 MOD-0, SUS. (Author's photograph.)

7. Category: Underwater. Group: Pyrotechnic Marker: Used for signaling or as floating markers, they emit smoke for daytime and flame for nighttime deployment. Can be deployed from aircraft, ships, or submarines, they contain Red Phosphorus (RP), pyrotechnic mixtures, or chemicals that react with water to produce fire or smoke. With so many different designs and applications, the materials used to provide smoke or fire can vary from 0.5 to over 5lb (0.23 to 2.3kg) and provide burn times of 10 to 30 minutes.

General identification features include (Figure 12.11):

Appearance and Materials:

- Multi-piece construction.
- Made of aluminum or wood on older designs.
- Sizes vary, the MK-25 Mod-4 (Figure 12.15) is 18.5×2.9in. (470×73.7mm).

- One end may have one or multiple "plugs" that will blow out to allow smoke or flame to exit.
- "Plugs" may have a rocket venturi appearance, without the additional components consistent with a rocket.

Markings: Silver, gray, or white body with red, black, or brown markings are common. Other colors, stamped or stenciled markings, and symbols may also be present.

Common Fuze Configurations: Some are manually armed, others are partially armed prior to deployment. After entering the water, soluble plugs dissolve to allow water to fill and activate a battery that electrically initiates the munition.

General Safety Precautions:

- Movement, fire.
- Chemical if burning, smoke is toxic.
- Do not look directly at a burning candle.
- Do not remove encrusted marine growth.
- Safety precautions for fuze, if present.

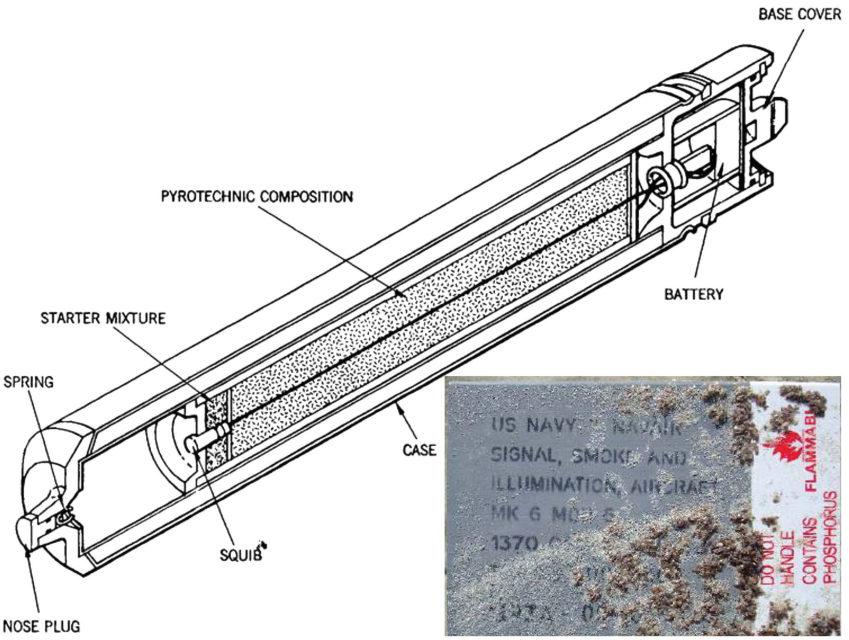

Figure 12.11 Internal configuration MK-25 Mod-4 pyrotechnic marker. (From U.S. Military TM). With inset picture of a MK-6 MOD-5 information from a munition recovered on a beach in New Jersey. (Author's photograph.)

Closing

Ordnance is commonly found on beaches, in fishing nets, and dredged off the sea floor. Ordnance designed to survive in harsh underwater environments has a high probability of functioning correctly after many years or decades underwater. Do not be fooled by the decayed outer appearance of ordnance that has been in an ocean or river for years or decades, since the internal components may be completely intact and pose a considerable threat. Consider the 2013 recovery of an almost completely intact U.S.-manufactured Howell torpedo that was recovered off the coast of San Diego, approximately 140 years after it was deployed. As seen in Chapter 13, the brass body allowed this torpedo to hold up well in the warm salt water that would have destroyed most ordnance within a few years.

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Historical Ordnance from all Applicable Categories

13

The more I read, the more I acquire, the more certain I am that I know nothing.

François-Marie Arouet de Voltaire

Introduction

When discussing military ordnance, no statement has been more based in fact than that of Voltaire; this fact is further reinforced when researching the historical origins of ordnance. As Winston Churchill said to the House of Commons in 1948, "*Those who fail to learn from history are doomed to repeat it,*" an understanding of how ordnance began and subsequently developed is critical. Unfortunately, when restricted to a single chapter, it is impossible to offer more than introductory information on the origins of an ordnance category or group. Thus, the primary focus of this chapter, as well as this text is safety and identification. For this reason, historical examples are included in most previous chapters, such as the background on grenade naming conventions in Chapter 6.

Unexploded ordnance (UXO) is regularly recovered during archeological excavations, and it is important to note two significant safety considerations. First, as long as it remains dry, black powder will not degrade and is capable of exploding in a 200-year-old munition. Secondly, mercury fulminate was the primary explosive used in early impact fuzing, and though it naturally degrades over time, it is important to keep two things in mind. First, if kept dry, it degrades slowly. Secondly, when configured in a glass vial; as in the Tice fuze (Section 7.b.), it will degrade very slowly, thus posing an explosive threat for a significant period of time. The good news is that historic ordnance can be safely inspected and, though sometimes difficult due to the loss of records, it can also be accurately identified. With this in mind, it is the hope of the author that efforts will be made to educate archeologists and the people supporting archeological efforts to help save historically significant ordnance for restoration and ultimately museum display.

Every piece of ordnance used today is the result of evolutionary processes running for years or centuries. In some cases, this evolution led to naming

conventions outside the norms, as seen with grenades. In other cases, understanding the initial intent behind the development of an ordnance category and group will answer questions concerning modern designs. Fortunately, no professional field operates in a bubble. When advancements in the field of chemistry result in new explosive materials, new engineering designs are seen in the shapes and configurations of ordnance. For example, after chemists developed formulas for smokeless propellants, physicists were able to reconfigure rocket motors, resulting in the man-portable, shoulder-fired rockets that remain an essential infantry weapon to this day. And information on historical ordnance is relevant and useful today as these munitions are encountered and recovered on a daily basis in the United States, all developed countries, and most other countries.

The intent of this chapter is to offer identifiable information associated with ordnance designed and manufactured prior to 1900. To do this, the chapter is broken into sections on explosives, grenades, projectiles, rockets, landmines, underwater ordnance, and fuzing. Each section offers introductory information, a specific example, and in some cases reference pictures, charts, or cutaway drawings.

Explosives

The information provided in this chapter is designed to enhance what is provided in Chapter 1 and Appendix D with additional background and developmental information. The timespan is specific to ordnance fillers used before 1900, during the initial transition to high-explosives in the late 1800s and early 1900s. As mentioned in Chapter 1, black powder, commonly known as gunpowder, served as the primary main charge, propellant, and fuzing explosive for hundreds of years.

The discovery of nitrocellulose in 1832 led to more breakthroughs throughout the 1840s, including guncotton, nitroglycerin, and collodion-cotton or more simply "collodion." By 1870, high-explosive guncotton was being used in hand-placed ordnance such as "torpedoes," the term for underwater mines during this time period. Sensitivity issues made guncotton unsuitable for use in fired ordnance such as projectiles or rockets as it often exploded prematurely upon firing. This fundamental flaw left only black powder or gunpowder as the primary main charge explosive used in most ordnance until the late 1890s.

With its use as a main charge explosive quashed, chemists, engineers, and physicists began to pursue other solutions. In 1889, collodion-type guncotton was combined with nitroglycerine in the manufacture of "cordite." The energy output and dependability of this new smokeless propellant led to rapid advancements in military rocket development; and civilian interest ultimately ushered in the age of modern rocketry.

The switch to high explosives happened in two phases, fuzing and main charges.

Fuzing: First patented for use in initiators by Scotsman Alexander Forsyth in 1807, mercury fulminate is the primary explosive first used to manufacture reliable primers, blasting caps, and detonators. The extreme sensitivity and reliability of this primary explosive was perfect for many fuzing system applications.

Main Charges: The change to high-explosive main charges was more convoluted due to numerous discoveries converging at different times. For example, picric acid was discovered in the mid-1700s, but its explosive characteristics were not appreciated until the 1830s. In 1871 the ability of picric acid to detonate was demonstrated by chemist Hermann Sprengel. By 1887, France, England, Japan, and many other countries were using picric acid singularly, or combined with guncotton or other materials as main charge explosives under many different names. In England, picric acid was made in Lydd, and named Lyddite; in Japan, a more stable picric acid-based explosive was named "Shimose" after engineer Shimose Masachika. Additional information on explosives is provided in Appendix D.

Trinitrotoluene, "TNT," was to become the future for high-explosive main charges in ordnance, but the transition took time. First introduced by Germany as a projectile main charge in 1902, many countries continued using picric acid through WWI. Thus, most pre-1900 ordnance utilized black powder for a main charge. However, the years between 1898 and 1914 were a time of transition and experimentation, followed by field tests on a massive scale as WWI raged from July 1914 through November 1918. Throughout the 20-year timespan between 1898 and 1918, ordnance manufactures experimented with every imaginable explosive concoction for use in high-explosive munitions. Many of these innovations relied on the use of a picric acid-based, main charge. See Appendices D, E, and G for information on marking schemes and pre-1900 projectile diameters.

Seven-Step Practical Process and Historical Ordnance

Examples of different designs, markings, and construction features are provided throughout this chapter.

Step 1: Gather Information, Approach, and Initial Inspection:

Attempt to identify from a safe distance with binoculars. Approach at a 45° angle from the rear to ensure the item is not modern ordnance with fuze sensing elements.

With sketch pad and camera, document identifying features including handles, fins, materials, construction features, stamped markings, damage, deterioration from exposure, signs of tampering or modification. Measure the width and length of each component.

The three fastest means of researching an unknown munition are:

1. Overall diameter and length
2. If applicable, the design and materials used to engage rifling
3. The design and materials used to make the fuze

Step 2: Determine Fuze Group, Type, and Condition:

If the fuze is damaged or alterations have been made, it is considered armed. If visible, measurements for the fuze are taken separately from the munition.

Step 3: Determine Ordnance Category:

Use the defining characteristics from each category to make this determination.

Step 4: Determine Ordnance Group:

Use the defining characteristics from each group to make this determination.

Step 5: Determine if Munition was Deployed:

Inspect for impact-related damage and deterioration from exposure to the elements.

Step 6: Determine Safety Precautions:

Safety precautions for the historical ordnance are covered in this chapter. Once identified, these precautions must be adhered to.

Step 7: Research Literature and Identify the Munition:

Apply the totality of measurements, stamped markings, materials, and construction features to determine the group, and positively identify the munition and fuzing configuration.

Categories

In order to provide congruency, the historical ordnance covered will include:

1. Projectiles
2. Rockets
3. Grenades
4. Landmines
5. Underwater Mines
6. Torpedoes
7. Fuzing

Projectiles

While black powder may have been used to propel munitions as early as the 11th century in China, the earliest documented use of black powder or

gunpowder in battle occurred in Europe. There is evidence of cannon being used early in the Hundred Years War. Accounts of the 1346 Battle of Crecy claim it as the first time combatants heard the explosive sound of cannon fire. Early cannons fired thick arrows called "bolts," also made of wood. Eventually wood-bolts were replaced by round balls made of stone. Such was the case in 1410 during the Battle for Malbork or Marienburg Castle when both sides possessed and deployed artillery. By 1462, massive projectiles fired from 560mm (22in) guns were used to destroy Bamburgh Castle, leaving little doubt that a new technology had come of age, changing warfare forever.

Soon the idea of filling a hollow cannonball with gunpowder was realized. As cannonballs were already being deployed in numerous ways with lethal effect, this was a logical technical development. Ironically, the U.S. Navy continued using cannonballs to engage other ships until the 1890s. Even at that time, the complex firing tables to support accurate ship-to-ship firing were not perfected. When an elongated projectile strikes water, it tends to dive, where a round ball will skip allowing gunners to aim at the ship and include a large amount of waterline in the firing calculations. The greater margin of error provided by cannonballs resulted in them being used for ship-to-ship engagements decades after elongated projectiles had become standard.

The number of cannonballs fired over the centuries is immense, which is why they continue to be recovered today. For example, according to John D. Bartleson, there were an estimated 10,000,000 projectiles fired by the Federal and Confederate armies during the U.S. Civil War (1861–1865). Another consideration, made more apparent during the four years of the U.S. Civil War, were the new fuzing designs and configurations made possible by the industrial revolution. Unfortunately, many new inventions and materials simply did not work, resulting in very high dud rates.

Definitions

In Chapter 4, some defining characteristics of modern projectiles are provided under "Projectile Sections and Defining Features." With changes to lexicon over the last hundred-plus years, using older terms will greatly hinder efforts to research an unknown munition. As such, definitions and some additional information are provided for a few older terms.

Firing an elongated projectile on a stable, accurate trajectory requires the coordination of numerous technologies, including the gun and propellant, neither of which are discussed here. Since black powder was the only propellant available at the time, it is mentioned for its use as a main charge, bursting charge, and in fuzing. For the projectile itself, the technological aspects associated with the propellant firing it, the materials and design of the rotating or driving band to engaging the rifling of a barrel, projectile shape, center of balance, and means of fuzing must all work in sync. All of these had

imperfections yet to be addressed prior to 1850, but the subsequent 100 years of evolution resulted in the projected ordnance in use today.

Concerning projectiles, with so many new manufacturing capabilities available in the mid to late 19th century, there were numerous technologies applied to stabilize a projectile in flight. Some worked, many did not, and a few designs drove changes to naming conventions of the time. Below are a few examples of important configurations, components, or technological hurdles from the mid-1800s, with reference to their present state.

Pounder -v- Caliber: Historically, the term "pounder" abbreviated "pdr" described a weapon system versus the projectile fired from it. This means a 6-pounder cannon fired a 6-pound projectile, which was true for 12, 24, 32 on into the hundreds of pounds. "Caliber," whether expressed in metric or standard measurements, is the actual diameter of the projectile being fired.

The pounder classification system worked well until hollow cannonballs, known as "shells," and filled with black powder, resulted in much lighter projectiles. The ability to fire an elongated projectile of different, usually heavier weight than its round counterpart, resulted in pounder designations following the do-do bird in all but some applications. For example, the British continued using the pounder designation for many munitions decades into the 20th Century and in some cases still do today.

Appendix G: Contains a chart with common projectile diameters for pre-1900 projectiles.

Fuse -v- Fuze: In most pre-1900 literature, ordnance fuzing was called fusing. Today, the burning time-fuse used for demolitions or the fuses used in electrical circuits are spelled with an "s." Where military ordnance uses fuze with a "z." Throughout this text the term fuze is used to avoid confusion. For research purposes, search for both fuse and fuze when working with ordnance manufactured prior to 1950.

Gaine: Today, the term booster or burster would be used to define the purpose served by a gaine.

Canister: The design of canister fired from guns has changed little over the last 200 years. Prior to 1800, this projectile was usually referred to as case-shot. After the introduction of the shrapnel shell, "canister" was used to distinguish these two different munitions. See Figures 1.3, 4.21 and 4.22 in Chapters 1 and 4, for examples of modern canister, grapeshot, and shrapnel projectiles.

Grapeshot: Would also be classified as canister today. When discussing historic ordnance, the difference between canister and grapeshot is primarily the size of the balls being fired, with grapeshot consisting of fewer balls of larger diameter. Grapeshot is usually configured with iron balls arranged on plates stacked 3 or 4 layers high, with a threaded bolt running through the center to securely hold everything tight until firing. Upon firing, the bolt snaps, turning the cannon into a massive shotgun.

Though it was used on land, grapeshot was used extensively at sea as it was favored for its overall effects in a ship-to-ship engagement.

Hotshot: A solid-shot projectile heated in a furnace until red or white-hot, then quickly loaded and fired into an enemy ship or fort. The super-heated cannonball would then ignite flammable materials it came into contact with, including ship timbers the shot came to be embedded in.

Polygonal-Cavity: Constitutes early techniques used to internally segment projectiles to produce uniform fragmentation size and 360° disbursement.

Driving Band: An older term used to describe a rotating band. See "sabot." Driving bands and rotating bands tend to stay on the projectile and are usually present when recovered in the field.

Sabot: Today, this term is usually associated with APDS projectiles (Figure 4.19, Chapter 4). However, sabot was also used to describe the materials, techniques, and base designs for early spin-stabilized projectiles. Often called a "driving band" in older literature, it is today named a rotating band. Materials used for sabots included wood, brass, copper, zinc, lead, papier-mâché, leather, and rope to name a few (Figure 13.1). Sabots tend to disconnect from the projectile after leaving the barrel and are usually not present when recovered in the field.

Rabbeted: The notches or grooves cut or cast into a projectile to secure the rotating or driving band.

Twist Rate: Represented in inches-per-turn, it is the rate of spin initiated as a projectile moves down the barrel when fired. When twist matches other firing characteristics, the result is gyroscopically stable flight.

Yaw: The amount of wobble a projectile has after leaving the barrel. If the means of engaging the rifling, twist rate, center of balance, and other design characteristics are not in sync, the result will be unstable flight or the projectile tumbling end-over-end until impact. For early elongated projectile designs, this was a major technical issue to overcome.

Groups

The historical projectiles covered in this chapter include:

a. Shot or Bolt
b. Carcass
c. Shell
d. Spherical Shrapnel
e. Elongated Shrapnel

1.a. Category: Projectile (Historic). Group: Shot or Bolt: A solid iron projectile, with no means of fuzing (Figures 13.1 and 13.2). Initial naming

Figure 13.1 U.S. 12-pdr strapped to wood sabot. (Author's photograph.)

Figure 13.2 British, 3in (76.2mm) Armstrong. (Author's photograph.)

conventions used the term "shot," but "bolt" is often used when referring to an elongated projectile.

The predecessor of modern armor piercing (AP) projectiles covered in Chapter 4, Section 4, these projectiles were designed to spall or penetrate ships and forts, as well as destroy enemy cannon. The Dahlgren Blind-Shell appears to be the first projectile specifically designed to penetrate armor, and successfully penetrated ironclad ships. The name is deceiving as the

Figure 13.3 U.S. 4.2in (106.7mm) Dahlgren Blind-Shell. (Author's photograph.)

"Blind-Shell" was hollow but contained no explosives, nor was it capable of being fuzed (Figure 13.3).

General identification features include:

Materials and Appearance:

- Round or elongated shape.
- Heavy body construction that comes to a dull point.
- Multiple or oversized rotating or driving band made of lead, wood, zinc, copper, or other materials.

Markings: Focus on construction features and stamped markings, such as manufacturer and foundry marks.

Common Fuze Configurations: None.

General Safety Precautions:

- Movement.

1.b. Category: Projectile (Historic). Group: Carcass: The transitional shift circa 1500, from firing a solid projectile to a hollow one capable of exploding required the invention of a fuzing system. The capability to do more with a munition resulted in an incendiary projectile called a carcass.

To make a carcass, a hollow ball with numerous holes was filled with an incendiary mixture. Concoctions varied, but most contained saltpeter and sulfur mixed with turpentine, sealed in the carcass with resin. A cotton wick fuse extended outside the ball. Fuzes could be lit prior to or during firing, and impact would force the incendiary filler out of the holes, to be ignited by the burning wicks as the carcass continued bouncing around.

By the mid-1600s, somewhat reliable fuze designs were emerging and the exploding shell would soon be a primary munition of choice. The success

associated with carcasses used in battle was apparent and these incendiary projectiles were used well into the 1800s.

General identification features include:

Materials and Appearance:

- Round or elongated shape.
- Metal or ceramic body with numerous external holes.

Markings: Focus on construction features and stamped markings, such as manufacturer and foundry marks.

Common Fuze Configurations: Wick-type.

General Safety Precautions:

- Movement, fire.
- Safety precautions for fuze, if present.

1.c. Category: Projectile (Historic). Group: Shell: A hollow projectile with a gunpowder main charge and a means of being fuzed. The techniques used to ignite the fuse sticking out of a carcass helped advance research into more reliable ways of fuzing a shell. For over 200 years, metal projectiles filled with black powder were the primary anti-personnel munitions used, until replaced by high-explosives in the 20th century.

General identification features include:

Materials and Appearance:

- Round or elongated shape.
- Heavy body construction that comes to a dull point.
- Multiple or oversized rotating or driving band made of lead, wood, zinc, copper, or other materials (Figures 13.1 and 13.2).
- Hole for a fuze-well.
- Fuze-well may incorporate an adapter to accommodate different fuzes.

Markings: Focus on construction features and stamped markings, such as manufacturer and foundry marks.

Common Fuze Configurations: Pre-1840: Time. Post-1840: Time, concussion, percussion, or combination fuzing.

General Safety Precautions:

- HE, frag, movement.
- Safety precautions for fuze, if present.

1.d. Category: Projectile (Historic). Group: Spherical Shrapnel (cannonball): By the late-1700s, the effects on personnel from projectiles exploding overhead versus after impacting the ground were understood by artillerymen. In 1792, a British artillery officer, Lieutenant Shrapnel looked for ways to further enhance these effects. The results of the soon-to-be general officer's research proved to be catastrophic for personnel caught in the open. These effects drove the need for troops to wear the hardened helmets seen today.

The original design consisted of a thin spherical shell (Section 1.c.) for the outer body. There were two methods used to configure the inside of the munition with a shrapnel mixture of lead or iron balls in a sulfur, pitch, tree rosin, or resin matrix that would set and harden. The first, involved filling the projectile then quickly wedging a wood dowel into the fuze well. The other, was to have two holes in the body, one for the fuze temporarily filled by a wood dowel and one to pour the bullet-resin mixture in. In both cases, the wood dowel was removed after the mixture hardened, allowing the burster charge to be added before the fuze was installed.

The second method involved filling the projectile with the original shrapnel mixture and allowing it to set. After hardening, the hollow cavity through the center of the munition is formed by drilling into the bullet-resin mix. The void is then filled with a gunpowder bursting charge and sealed in with a powder train time fuze (PTTF).

General identification features include (Figure 13.4):

Materials and Appearance:

- Round shape.
- May have an externally attached sabot to impart spin.
- Thinner side-wall construction than a shell.
- Hole for a fuze-well.
- May also have a filler-hole, smaller in diameter than the fuze-well.
- Fuze-well may incorporate an adapter to accommodate different fuzes.

Markings: Focus on construction features and stamped markings, such as manufacturer and foundry marks.

Common Fuze Configurations: Time fuzing.

General Safety Precautions:

- HE, frag, movement.
- Safety precautions for fuze, if present.

1.e. Category: Projectile (Historic). Group: Elongated Shrapnel: The overall concept of round or elongated shrapnel rounds is the same; however,

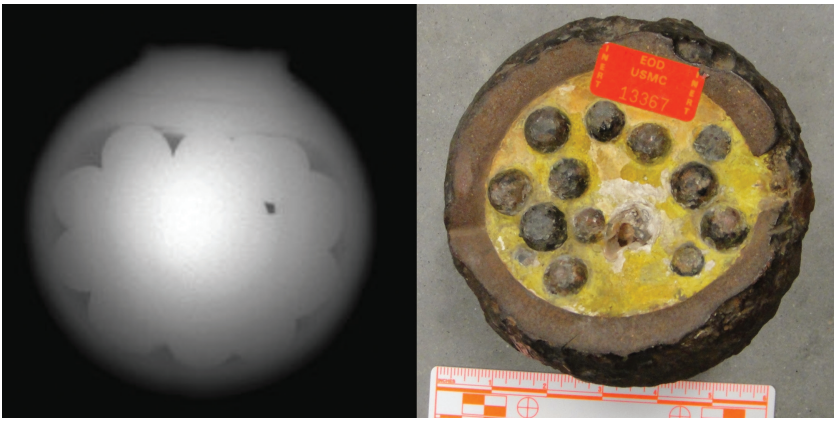

Figure 13.4 U.S. 12-pdr shrapnel projectile. (From U.S. Military TM, and author's photograph.)

elongated projectiles were adopted after functional rifling designs had been developed. The original design incorporated a bursting charge running down the center of the projectile with a large explosive charge in the base. What evolved into the WWI shrapnel projectiles covered in Chapter 4, Section 5.b. began like the example in Figure 13.5.

With new materials available and the equipment required to use them, the technological advancements in ordnance manufacturing between the mid-1800s and beginning of the 20th century is mindboggling. Yet, the

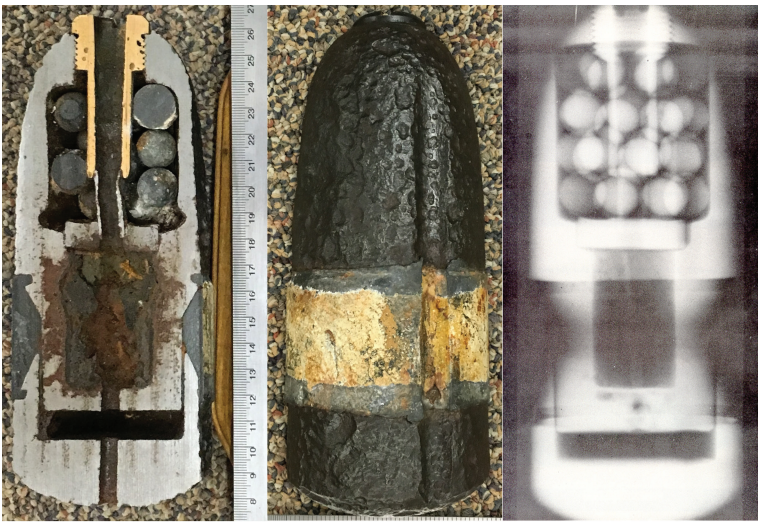

Figure 13.5 U.S. 3in (76.2mm) Hotchkiss shrapnel projectile. Note the burster running from the fuze, down the center to the base charge. (Author's photograph and x-ray from U.S Military TM.)

original design of the elongated shrapnel projectile experienced only one significant change. In order to focus the shrapnel in a specific direction, the tube housing the bursting charge running down the center of the projectile was left hollow, the size of the black powder charge in the base was increased, and the remaining 80% of space within the projectile was filled with lead or iron balls "shrapnel" that may or may not be mixed with a sulfur, pitch, or resin matrix.

Reconfigured this way, the flame produced by the fuze would travel down the center of the projectile to initiate the explosive charge in the reinforced base that retains its shape. Upon exploding, the black powder propels the fuze, adapter, and payload of shrapnel in a forward direction, thus providing directionality for the shrapnel. During WWI, shrapnel projectiles were used to engage personnel in the open as well as to sweep trench lines clear of troops.

General identification features include (Figure 13.5):

Materials and Appearance:

- Elongated shape with a means of engaging rifling.
- An adapter to accommodate the fuze and secure the tube running from the fuze to the explosive charge in the base.
- Hole for a fuze-well.
- Fuze-well may incorporate an adapter to accommodate different fuzes.

Markings: Focus on construction features and stamped markings, such as manufacturer and foundry marks.

Common Fuze Configurations: Pre-1840: Powder-train-time-fuze (PTTF). Post-1840: PTTF or combination fuzing.

General Safety Precautions:

- HE, frag, movement.
- Safety precautions for fuze, if present.

Rockets

Early rocket designs ranged from bamboo to iron bodies, filled with gunpowder or incendiary mixtures set at the end of a long wood pole, to a gyroscopically stabilized munition. As such, this section will focus on a few considerations not covered in Chapter 5. Concerning the explosives, incendiary, and construction materials used, the history of rockets and projectiles

are very similar. Prior to the late-1800s, the biggest differences between the two were:

1. Rockets could be fired much further than projectiles but were exceptionally inaccurate.
2. Upon firing a projectile, there was a small chance of the gun exploding; but when firing rockets, there was a good chance of a premature explosion that could injure or kill crewmembers.

Prior to the use of cordite and other smokeless propellants, a soldier assigned to a "rocket company" was perceived by many as having received a death sentence. This perspective led to moral issues, and limited use of rockets for hundreds of years. They were first used when black powder was put in bamboo bodies, called "fire arrows" by the Chinese, while fighting the Tartars in 1312. By 1380, Genoese ship-mounted rockets were fired against Venice's fortifications with good results during the Battle of Chioggia, Italy. In India, rockets were used with very good effect throughout the Fourth Anglo-Mysore War in 1799. In July 2018, over 1,000 of these metal rockets were recovered in the area. Though there were limited successes, the overall tactical impact rockets had on the battlefield prior to 1900 appears to be more psychological than physical.

An example of an ingenious rocket application is that of calcium oxide (quicklime). It was used during the U.S Civil War as an early illumination munition. Invented in the 1820s, the illuminating capabilities of calcium oxide was used in theaters, leading to the term "to be in the limelight." During the Civil War, northern forces used rockets with calcium oxide warheads to illuminate Confederate fighting positions and ships attempting to run blockades. Due to the rarity of munitions such as these, rockets with an explosive warhead will be the only group covered.

Groups

The historical rockets covered in this chapter include:

a. Explosive.

2.a. Category: Rocket (Historic). Group: Explosive: Designed to explode and destroy targets with blast, fragmentation, and thermal effects. Explosive fillers in these rockets range from ounces to pounds of black powder or guncotton.

General identification features include:

Materials and Appearance:

- Warhead of light body construction to decrease weight.
- Pole or fin assembly on the aft end, or

- One or more slanted venturis on the base of the motor.
- Hole for a fuze-well.
- Fuze-well may incorporate an adapter to accommodate different fuzes.

Markings: Focus on construction features and stamped markings, such as manufacturer and foundry marks.

Common Fuze Configurations: Pre-1840: Time. Post-1840: Time, concussion, percussion, or combination fuzing.

General Safety Precautions:

- HE, frag, ejection, movement.
- Safety precautions for fuze, if present.

Hand Grenades

An overview of grenades was provided in Chapter 6. With rifle grenades and projected grenades coming of age after 1900, this section will focus on early incendiary and explosive hand grenades.

Early hand grenades were often small cannonballs with a manually lit fuze. Throwing a 12-pound ball may not be feasible, but a 3-pound ball can be thrown far enough to make it a viable option. During the U.S. Civil War, the Ketchum grenades in Figure 13.6 were used in 1-pound, 3-pound, and 5-pound versions along with many other designs such as the spherical grenades in Figure 13.7.

Groups

The historical hand grenades covered in this chapter include:

a. Carcass
b. Fragmentation

3.a. Category: Hand Grenade. Group: Carcass-Incendiary: Carcass hand grenades were made in a similar fashion to a carcass fired from a cannon, but with much simpler fuzing. An example of a carcass grenade design would be a hollow ceramic sphere about the size of a baseball (3.3in or 84mm), with four to seven holes in the body. The inside of the ball is filled with a saltpeter, sulphur, and turpentine mixture, or other incendiary materials sealed inside with resin. A manually lit, simple cotton-wick-fuze extended outside the ball. These grenades were designed to be thrown against a hard surface so the outer shell would break, allowing the incendiary mixture to spread as it was ignited by the burning wick.

A common battlefield application would have sailors and marines climb onto mast platforms known as "fighting tops" to throw these grenades onto an enemy ship as is believed to have happened during the Battle of Flamborough Head during the American Revolution. After hours of fighting both ships were badly damaged, when the Bon Homme Richard fired a broadside into the Serapis, but two of the 18-pounder guns exploded. The explosions blew out the deck above, killed many men, and spelled defeat for the Americans. A carcass grenade thrown by an American sailor went through a hatch, down to the Serapis's gun deck and exploded. The grenade ignited powder and ammunition resulting in a massive explosion killing or wounding most of the Serapis crew, resulting in its surrender.

General identification features include:

Materials and Appearance:

- Round shape.
- Ceramic body with numerous external holes.

Markings: Focus on construction features and stamped markings, such as manufacturer and foundry marks.

Common Fuze Configurations: Wick-type.

General Safety Precautions:

- Movement, fire.
- Safety precautions for fuze, if present.

3.b. Category: Hand Grenade. Group: Fragmentation: Designed to provide infantry with a hand-deployed weapon capable of producing blast and fragmentation effects. Most contain between 1oz to 6oz (28gr to 170gr) of gunpowder in a cast-iron body.

General identification features include:

Materials and Appearance:

- Round or elongated shape.
- Cast iron body with a fuze-well.

Markings: Focus on construction features and stamped markings, such as manufacturer and foundry marks.

Common Fuze Configurations: Depending on the time period, fuzing ranged from simplistic wick-type, to nose-impact (U.S Ketchup

grenade [Figure 13.6]) pull-friction (U.S. Adams grenade), and all-ways-acting (U.S. Hanes grenade).

General Safety Precautions:

- HE, frag, movement.
- Safety precautions for fuze, if present.

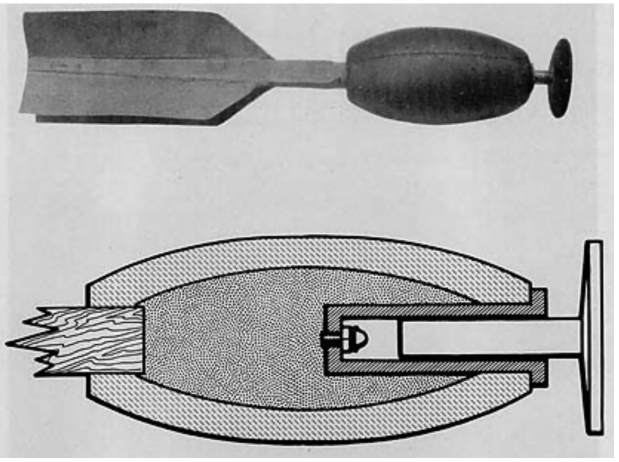

Figure 13.6 U.S. Ketchum grenade, came in 1lb, 3lb, and 5lb (.45kg, 1.36kg, and 2.27kg) versions. The plunger is held in place with side-mounted springs until impact with the target. (From U.S. Military TM.)

Figure 13.7 U.S. Confederate, 1.5lb (.68kg) hand grenades with wood-plug fuses. Recovered by Steve Philips from the Alabama River near Selma, Alabama. (Courtesy of William E. Lockridge.)

Landmines

The first victims of what would be classified as a "landmine" today, came in 1862 when Union forces were pursuing Confederates under the command of General Gabriel Rains. The general had his troops bury cannonballs with pressure actuated fuzing (Figure 13.8). These landmines, later known as the "Louisville Road Torpedo," were set just below the surface in the hope of slowing pursuit. The unexpecting Union troops then stepped, with foot or hoof, on the fuze, crushing the thin outer membrane against a primer, exploding the mine. Those killed or injured represented a small fraction of the tactical implications of this new weapon, as the panic resulting from men running from the unknown threat caused significant hysteria and confusion across the battlefield.

Within months, the Confederate War Department formed a division to develop mine warfare on land and water. The moral and ethical arguments arising from the use of landmines spread around the world. By the mid-1870s, most advanced countries were developing, manufacturing and ready to deploy landmines.

General identification features include:

Materials and Appearance:

- Usually consist of a projectile shell.

Markings: Focus on construction features and stamped markings, such as manufacturer and foundry marks.

Figure 13.8 U.S. Confederate, 24pdr converted for use as a landmine. Fitted with a Britten Percussion Fuse that functions when crushed. (From U.S. Military TM.)

Common Fuze Configurations: Pressure actuated and electrically fired-command initiated. Initial designs were modified artillery percussion fuzes. Later designs were similar to those covered in Chapter 10.

General Safety Precautions:

- HE, frag, movement.
- Safety precautions for fuze, if present.

Underwater Mines

As mentioned under landmines, the Confederate War Department formed a division to develop underwater mines, which were called "torpedoes" at this time. Prior to the Crimean War and U.S. Civil War, brick and mortar forts were able to withstand a substantial number of hits from cannonball-type projectiles. They were not able to hold up to the increased velocity and impact physics associated with spin-stabilized, elongated projectiles. As such, immediate efforts were made to deny enemy ships the ability of approaching forts or accessing waterways. Initial designs included tar-coated beer kegs, and glass demijohn bottles. By the end of the U.S. Civil War in 1865, large boilers containing 10,000lb (4,536kg) of explosive were being deployed for this purpose.

The most difficult aspect of successfully deploying underwater ordnance is the fuzing. Water would neutralize most historic fuzing configurations, making water-proofing and controlled means of functioning mines the primary focus for research and development. As mentioned in Chapter 2, during the August 1864 Battle of Mobile Bay, sailors could hear the mines scraping along their ships' bottoms without exploding. It was later learned that these mines had spent months in the water, resulting in the fuzing becoming soaked and not functioning as designed. During the December 1864 attempt to capture Fort Branch in North Carolina, the Union Navy recovered over a dozen mines in the water at Jamesville where the USS *Otsego* and USS *Bazewell* sank. By the end of the Civil War, the Union had lost more ships to torpedoes than all other threats and actions combined, solidifying the use of these munitions well into the future.

General identification features include:

Materials and Appearance:

- Wood, glass, or metal body.
- Anchored in place with rope or chain.
- Multiple fuze-wells.

Markings: Focus on construction features and stamped markings, such as manufacturer and foundry marks.

Common Fuze Configurations: Pressure actuated and electrically fired-command initiated. There are historical accounts of floating mines fixed with burning time fuse, used to float near enemy ships or tangle in anchor lines before the fuse would burn down and explode the mine.

General Safety Precautions:

- HE, frag, movement.
- Do not remove encrusted marine growth.
- Safety precautions for fuze, if present.

Torpedoes

The term "torpedo" has been used to describe a number of ordnance items. The original torpedo consisted of a 50lb to 100lb (22.5kg to 45kg) explosive charge in a metal body, fixed to the end of 14ft to 20ft (4.3m to 6.1m) spar mounted on the front of a vessel. The attacking vessel would lower the spar so that it was pointing forward, and either ram the enemy ship allowing a percussion fuze to function or attempt to place the torpedo below the waterline against a ship's bottom before manually functioning the fuze. The most historic use of a spar-torpedo would be the February 1864, Confederate submarine *H.L. Hunley's* attack on the USS *Housatonic* in Charleston Harbor, resulting in the *Housatonic* becoming the first ship to be sunk by a submarine. Recovered in 2000, the *Hunley* is on display in the Warren Lasch Conservation Center in North Charleston, South Carolina. The next application for the term torpedo was to describe what is now known as a moored mine.

The first "torpedo" as defined in Chapter 12, was the "Whitehead torpedo" developed in 1866. The first U.S. design was the "Howell torpedo" in 1870 (Figure 13.9). The 12in (305mm) diameter, by 11ft (3.35m) Howell

Figure 13.9 U.S. Howell Torpedo, made in the 1870s. Photograph from the U.S. Naval War College Museum website. In March 2013, Howell torpedo #24 was recovered by Navy EOD off the coast of San Diego, California.

torpedo could carry its 100lb (45.36kg) guncotton warhead at a staggering 25-knots, underwater for 400 yards (366m) in the 1870s.

General identification features include:

Materials and Appearance:

- Multi-piece construction.
- Made with high quality materials and machining.
- Propeller on aft end.
- Vertical fins toward the aft end with movable surfaces for direction changes.
- A shroud encircling fins to protect the screws.

Markings: Focus on construction features and stamped markings, such as manufacturer and foundry marks.

Common Fuze Configurations: Impact fuzing

General Safety Precautions:

- HE, frag, movement, and ejection for the propellers.
- Do not remove encrusted marine growth.
- Safety precautions for fuze-exploder, if present.

Fuzing

When discussing the capabilities and limitations of a specific piece of ordnance, each component must be considered separately before the effectiveness of the overall munition can be ascertained. In this context, the fuze constitutes the "brains" of a munition; without an effective fuze, an explosive munition is little more than scrap metal with a hazardous filler. The quote from Commander Dahlgren at the beginning of Chapter 3 provides insight on the lack of substantial fuzing improvements from the early 1600s to the early 1800s.

In March 1863, a series of explosions on Brown's Island temporarily shut down the Richmond Arsenal. As the Army of Northern Virginia prepared for the invasion of Pennsylvania, artillery fuzes from the Charleston Armory were provided due to the Brown's Island explosion. Fast-forward to the afternoon of the third day of the Battle of Gettysburg. At 1 p.m., approximately 140 Confederate guns opened a sustained two-hour bombardment on the center of the Union defensive lines. The intent of this, the largest concentrated artillery barrage in North America at the time, was to soften Union defenses for the all-out attack of circa 12,000 infantry. Unknown to the Confederate artillerymen, the Charleston time fuzes burned slower than the Richmond

Arsenal fuzes, and the dense black powder smoke quickly obscured the target area. The majority of shells and case shot passed over Union infantry before exploding a hundred yards or meters behind them. The result was a virtually untouched defensive line hidden by the "fog of war" when "Pickett's Charge" commenced. This historic episode is an example where a half-second difference in fuze functioning had significant impact on an attack, a battle, a campaign, the outcome of a war, the future of a country, and the future of the world.

Lessons learned from the Crimean War (1853–1856), U.S. Civil War (1861–1865), and other mid-19th century conflicts were evident in the ordnance designs deployed during the Franco-Prussian War (1870–1871) and other conflicts in the late 1800s. Nowhere are these new technological developments more evident than in fuzing designs and functionality, many of which are still used today. Lastly, with the large majority of rocket, grenade, landmine, underwater mine, and torpedo fuzing being adaptations of projectile fuzes, this section will highlight this area.

The defining information provided in Chapter 3 on fuze design and functioning applies here. The fuzing groups and types covered are:

1. Time
2. Concussion
3. Percussion
4. Combination

7.a. Category: Fuze (Historical). Group: Time: Early time fuze designs were all powder-train-time-fuzes (PTTFs) as seen in Chapter 3, Section 3. Designed to function a munition while in flight, time fuzes were used exclusively on case-shot shrapnel projectiles and to a lesser extent on shells. By function, there were two designs, self-igniting and those lit by the flame produced from the propellant during firing. Figure 13.10 shows a fuze of older configuration, with the new self-igniting feature, where Figure 13.11 is a configuration still used today while utilizing the old method of igniting the powder-train-time delay.

Early time fuzes consisted of a hollow paper or wood body filled with pressed black powder. Vertical holes were cut to the side and the entire fuze was wrapped and sealed in treated paper. Commonly referred to as a "paper-time fuze," the side-cut holes corresponded to burn times represented by numbers running down the side of the fuze, as seen in Figure 13.10. Prior to firing, a hole would be punched on the spot representing the desired time delay. Then, when the black powder core burned down to the opening, the flame would escape through the hole and shoot into the bursting charge in the munition causing it to explode. Time delays were usually set in one-quarter-second increments, meaning a projectile

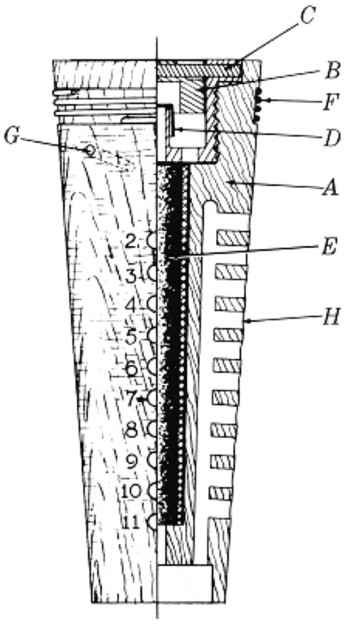

Figure 13.10 British, Boxer, Self-igniting Time Fuze. (From U.S. Military TM.)

moving approximately 800 fps (244 mps) will function within a 200ft (61m) window. Standardized fuze adapters were installed in projectiles of various sizes and shapes to ensure the fuze was seated correctly, allowing it to function as designed.

The Bormann fuze (Figure 13.11) was a Belgian design that made its way to the U.S. in the 1850s, but there were manufacturing issues that caused premature functioning. During the Civil War, manufacturing changes in the North addressed these problems resulting in a highly reliable Bormann fuze. In the South, these problems were never fully overcome and the old-style paper time fuzes were more commonly used.

As seen in Figure 13.11 the Bormann design was substantially different from previous paper-time fuze designs. The "C-shaped" channel was filled with pressed black powder. To set the fuze, a notch was cut at the quarter-second interval on the face. Upon firing, the projectile was enveloped in flame from the propellant, igniting the powder-train, which burned down and functioned the munition. Examples of later Powder-Train-Time-Fuze (PTTF) designs can be seen in Figures 3.11 and 3.12, Chapter 3. Comprised of stacked up Bormann fuze C-shaped channels, the M1907 in Figure 3.11 had a 21-second maximum set time. The longer burn-time made it a natural developmental step when the initial 5½-second and later 10½-second maximum set time for Bormann fuzes could no longer accommodate longer range artillery.

Figure 13.11 U.S. Bormann Time Fuze in a 12pdr shell. The "A" is the Alleghany Arsenal symbol. (From U.S. Military TM and author's photograph)

General identification features:

Materials and Appearance:

- Fuze adapter with a standard screwdriver slot or two spanner holes. Made with brass, zinc, and other metals.
- If a fuze adapter is present, a paper-time fuze was intended to be used with it.
- Bormann fuze was made of pewter (a tin–lead mixture).
- Post U.S. Civil War PTTFs have one brass component housing the pressed black powder train or are completely brass.
- Later brass, multipiece-stacked designs have vent holes or gaps between layers to allow for air to get in and smoke to escape.

Markings: Timing increments are usually stamped on the fuze. By the end of the 1800s, most fuzes also had stamped nomenclature as well.

General Safety Precautions:

- HE, frag, movement, W/T.

7.b. Category: Fuze (Historical). Group: Concussion: Referred to as an "all-ways-acting" fuze today, it was initially named a "concussion" fuze. Designed to function upon impact as the fuzes in Chapter 3, Section 1, concussion fuzes could be used with spherical or elongated shells and case-shot projectiles. As it is impossible to ensure the orientation of a sphere upon impact, a concussion fuze had to function regardless of the angle of impact.

The Tice fuze (Figure 13.12), due to its unique configuration, can pose a significant hazard to this day. Note the mercury fulminate housed in a glass vial (Figure 13.12, letter I). Upon impact, the vial should have broken, resulting in an explosion. Mishandling of this fuze can still result in a catastrophic outcome.

General identification features:

Materials and Appearance:

- Fuze is threaded directly into the munition.
- Made with brass, copper, zinc, and other metals.
- May have a standard screwdriver-like slot on top.

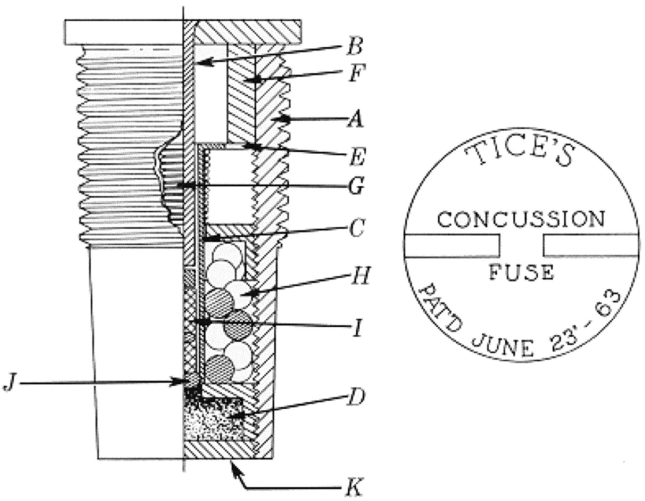

Figure 13.12 U.S. Tice, Concussion Fuze, with glass vial (I) of mercury fulminate. (From U.S. Military TM.)

Markings: If made of brass or copper, the fuze name and patent date may be cast into the face of the fuze and may be completely legible after 150+ years in the ground or water environments.

General Safety Precautions:

- HE, frag, movement.

7.c. Category: Fuze (Historical). Group: Percussion: Made specifically for use in elongated, spin, or fin stabilized projectiles, a percussion fuze requires direct impact to function as designed.

The simplistic line drawing in Figure 13.13 shows a common configuration with an added safety. The wire (letter E) holds the striker and primer (C and F) until the impact inertia from significant impact breaks the wire, freeing the striker to slam forward driving the primer into the anvil (B) functioning the fuze. In addition to this sliding-striker design, there are also crush-type percussion fuzes. An example of a fuze modified for other applications is the crush-type percussion fuze used in landmines, described in Section 4 of this chapter.

General identification features:

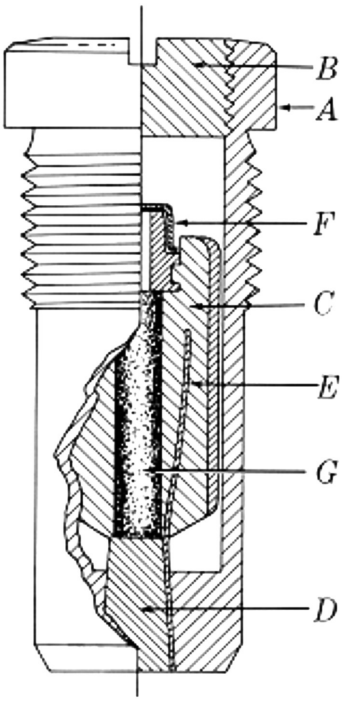

Figure 13.13 U.S. Hotchkiss, Percussion Fuze. (From U.S. Military TM.)

Materials and Appearance:
- Fuze in threaded directly into the munition.
- Made with brass, copper, zinc, and other metals.
- May have a standard screwdriver-like slot on top.

Markings: If made of brass or copper, the fuze name and patent date may be cast into the face of the fuze and completely legible after 150+ years in the ground or water environments.

General Safety Precautions:
- HE, frag, movement.

7.d. Category: Fuze (Historical). Group: Combination: Capable of functioning via time or percussion, combination fuzing was the predecessor of modern PTTF with impact backup, or the mechanical time-super quick (MTSQ) fuzing described in Chapter 3, Section 3.a and 3.b (Figure 13.13).

As scientists and engineers focused on stabilizing flight and increasing range, emphasis was put on engaging the rifling. However, some driving-band designs were so efficient at trapping gas behind the projectile, the flame required to ignite the fuze were also trapped, resulting in a dud-fired projectile. Efforts to address this include "flame grooves" cut into sabots or the entire length of a projectile (Figure 13.5), as well as the development of combination fuzing.

General identification features:

Materials and Appearance:
- Fuze is threaded directly into the munition.
- Made with brass, copper, zinc, and other metals.
- May have a round-dome or flat-nut shape.

Markings: Early versions tend to have no markings.

General Safety Precautions:
- HE, frag, movement.

Closing

The ordnance covered in this section constitutes the early developmental stages of ordnance used today. To fully understand what the scientists, engineers and inventors were trying to make, refer to the appropriate chapter to see how a similar munition functions in the present.

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Closing 14

Unless you try to do something beyond what you have already mastered, you will never grow.

Ralph Waldo Emerson

Chapter 1 provides an overview of the explosives and hazardous materials used in military ordnance. Chapter 2 provides a scientific method in the form of a practical deductive process that should be applied when inspecting unknown ordnance. Chapters 3 through 13 follow the systematic breakdown of the Category/Group ordnance classification system (Appendix A, Logic-tree 2), all of which focus on a few central themes. First, ordnance should only be handled by appropriately trained personnel. Second, though larger ordnance items are briefly covered, the focus of this text is on the smaller munitions more commonly recovered outside of military control. It is important to keep these limiting factors in mind when using this text as it is impossible to cover all military ordnance in one library, much less a single book. Lastly, there are many explosive devices utilized by the military that are not covered in these chapters. For example, seldom seen or extremely rare ordnance configurations such as glass, porcelain, and pottery grenades manufactured by Germany and Japan during the latter part of WWII may not be easily recognized (Figure 14.1). Other configurations, such as Figures 14.2 and 14.3, may include components from different categories, groups, or countries, assembled together. Though classified as ordnance, properly categorizing and grouping these munitions in order to apply the appropriate safety precautions may be difficult. However, by following the seven-step process, either the category or group, as well as the safety precautions are usually identifiable, allowing a person to continue working in the safest manner possible until the munition is identified. See Appendices D and E for information on marking schemes.

There are explosives and hazardous materials used by the military that are not classified as ordnance. Some are marked with ordnance schemes, most are not. However, when recovered outside military control, these items pose significant threats. For example, the Naval Explosive Ordnance Disposal School devotes considerable curriculum to "Aircraft Explosive Hazards," which are not covered in this text. These explosive hazards include the components used to blow-off or shatter the canopy of a fighter jet, the

Figure 14.1 Left: German, WWII-era "Glashandgranaten Type A" translated, glass hand grenade. Right: Japanese WWII-era pottery hand grenade. (Left: Author's photograph. Right: Photograph courtesy of Dan Evers.)

Figure 14.2 Russian 60mm HE mortar body with a plugged fuze-well and a modified base allowing the introduction of a hand grenade fuze. (Photograph courtesy of Didzis Jurcins.)

Figure 14.3 Bulgarian 40mm Projected Grenade. Appears to be a U.S. M433 body with a Hungarian version of the Russian VOG-25 fuze. (Author's photograph.)

explosive components and rockets used to separate and subsequently eject a pilot from an aircraft, then deploy and explosively open the parachute, but these components are classified as escape systems. Other hazards such as the chaff and flares that are explosively ejected to burn or disperse materials designed to attract guided missiles are not covered, as they are classified as countermeasures. There are also training simulators, which are pyrotechnic devices designed to simulate battlefield noises and effects (Figure 14.4). Classified as "special fireworks," these landmine, grenade, and artillery simulators are usually constructed of cardboard or plastic. Most contain photoflash powder, designed to produce a strong concussive effect or whistling sound prior to exploding. However, the "Gunflash" simulator in Figure 14.4 is especially dangerous to those not closely following the directions, which are usually not provided when issued. The final example is "trench art" which can include any piece of ordnance, fragment, or cartridge case used to make a souvenir. The examples provided in Figure 14.5 are a commonly recovered WWII souvenir.

These examples are provided to reinforce the "movement" safety precaution listed for every ordnance category and group. Applying the seven-step practical process to unknown ordnance, modified munitions, and military

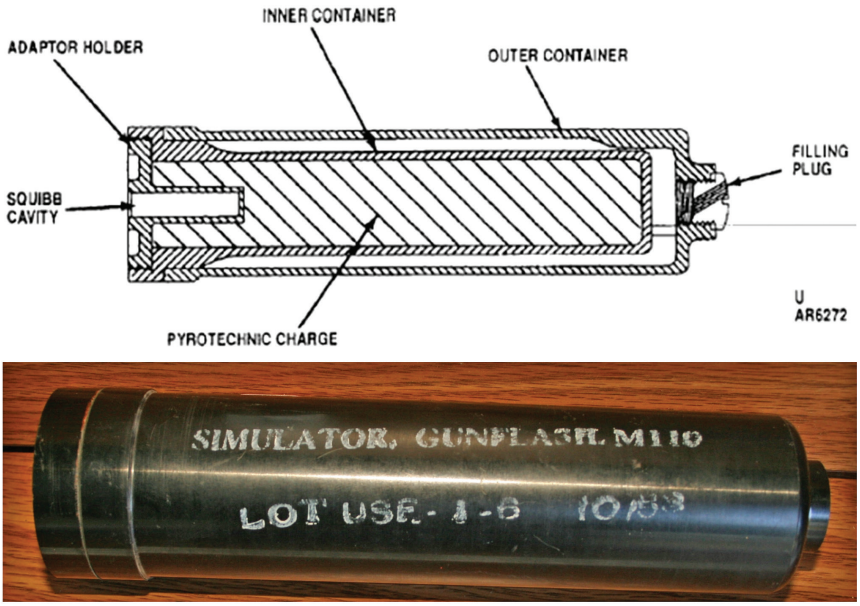

Figure 14.4 U.S M110 "Gunflash" simulator. By design, the filling plug is removed and the void surrounding the substantial photoflash charge is filled with fuel. Items such as this are extremely dangerous if misused. (From U.S. Military TM.)

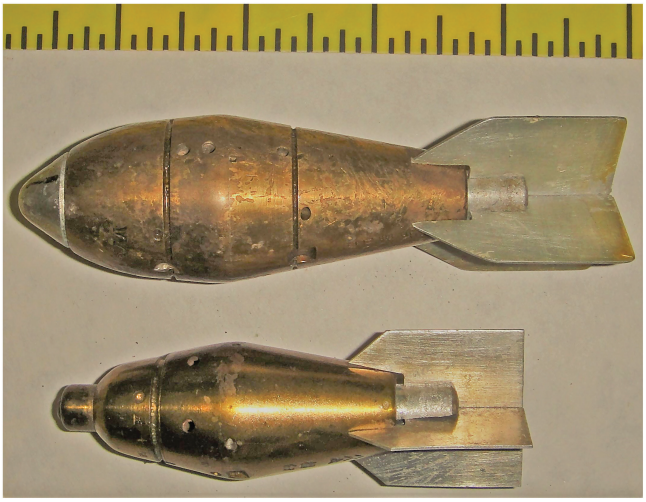

Figure 14.5 Trench art. Japanese WWII-era projectile fuzes, with detonators and boosters removed, turned base-to-base and screwed into each other with homemade fins attached. (Author's photograph.)

items falling outside the ordnance classification structure (Figures 14.1 through 14.5), do not immediately move it. A suspect item should not be touched or moved by a person who does not know what it is, how it works, or its condition. All of which is determined through research. When applied to the study of military ordnance, replace "try" with "learn" and Emerson's quote at the beginning of the chapter is fully appreciated.

The discovery of ordnance outside military control is a daily occurrence. Those finding these munitions include beach goers, hikers, police officers, firemen, history enthusiasts, archeologists, public utility personnel, and TSA personnel manning security checkpoints to name a few. To ensure public and personal safety, consider applying the process laid out in Chapter 2 when encountering an unknown item that could be ordnance, a component of larger ordnance, a countermeasure, part of an escape system, special fireworks, trench art, or an item with markings suggesting it is designed for military applications.

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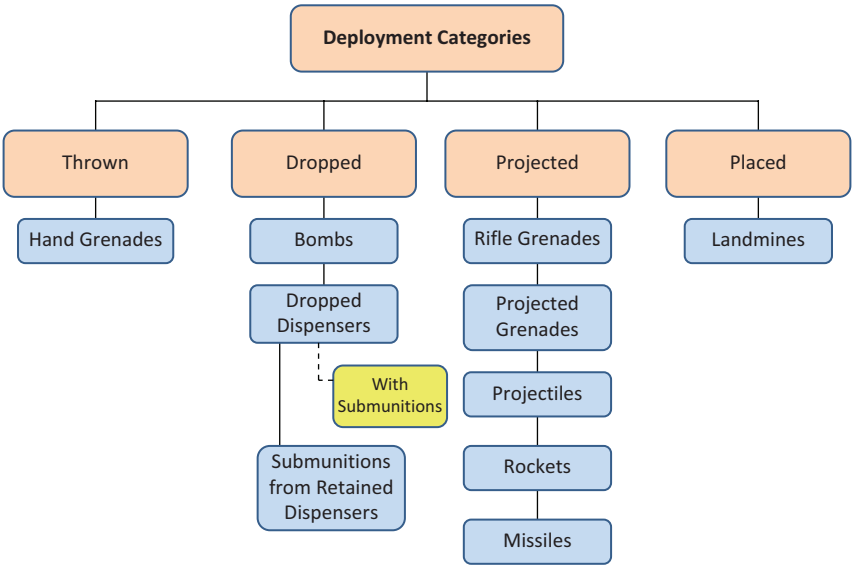
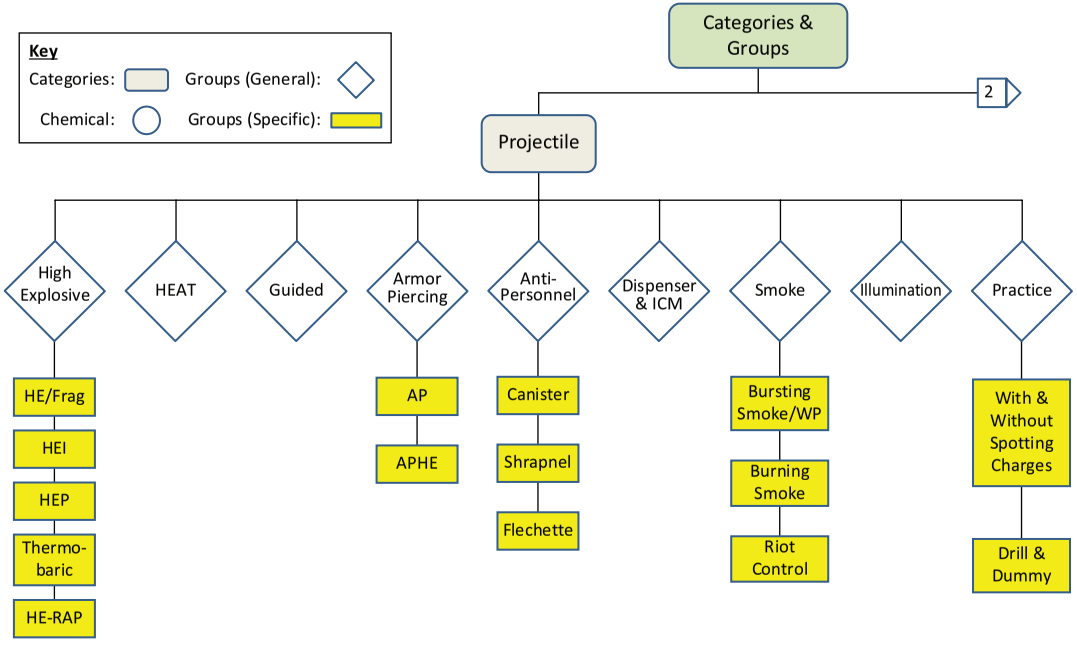
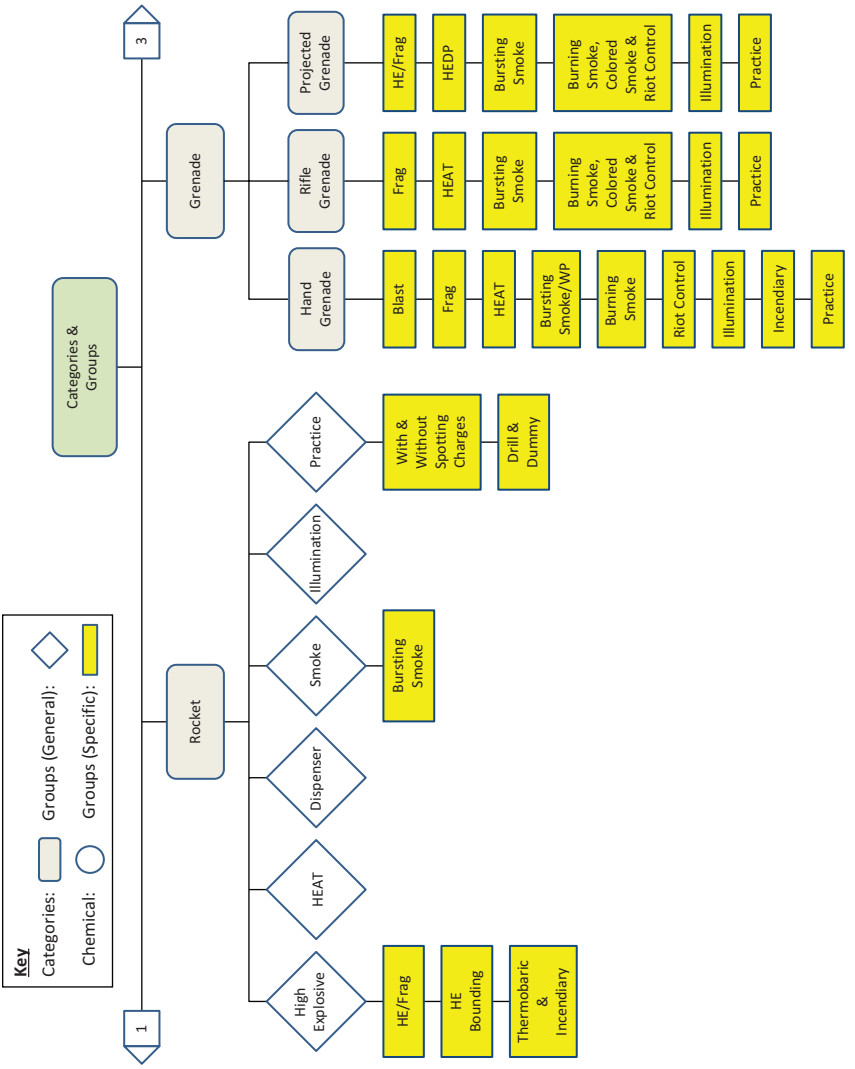
Appendix A: Logic Trees

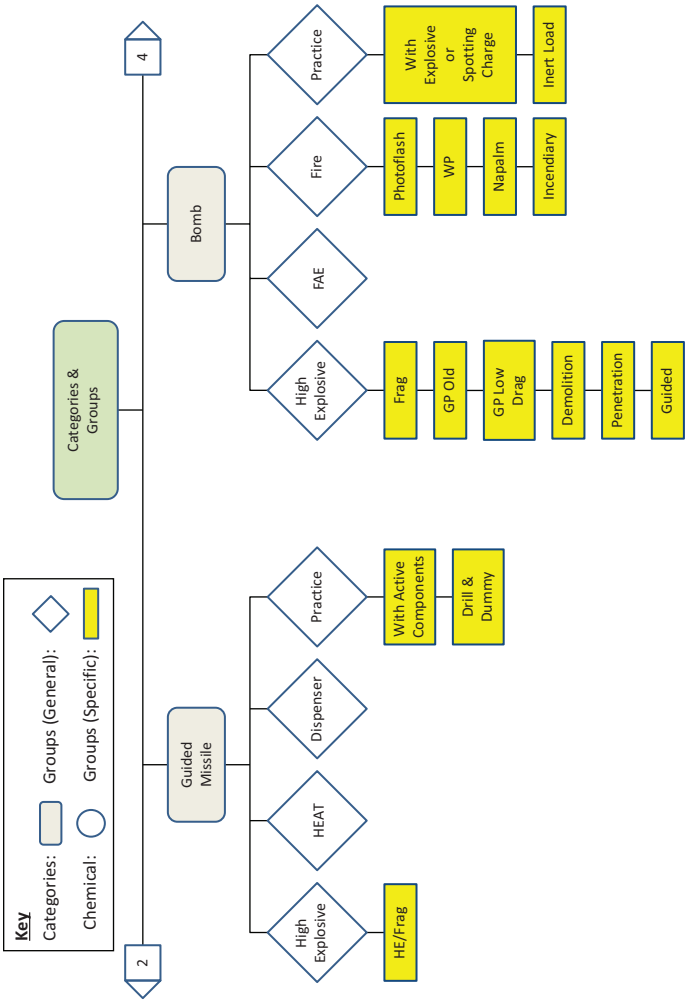
Logic Tree 1 – Methods of Deployment

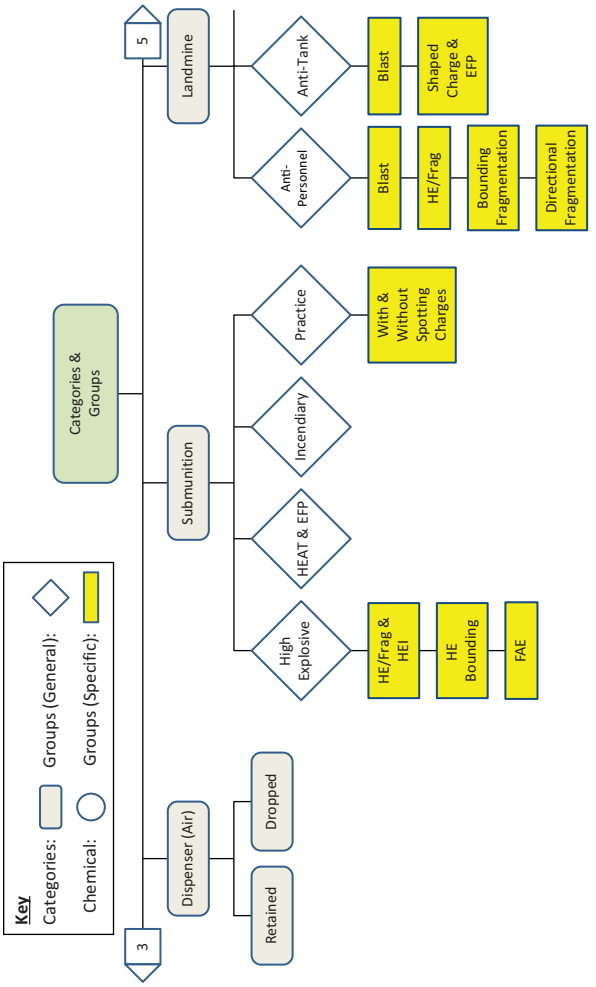


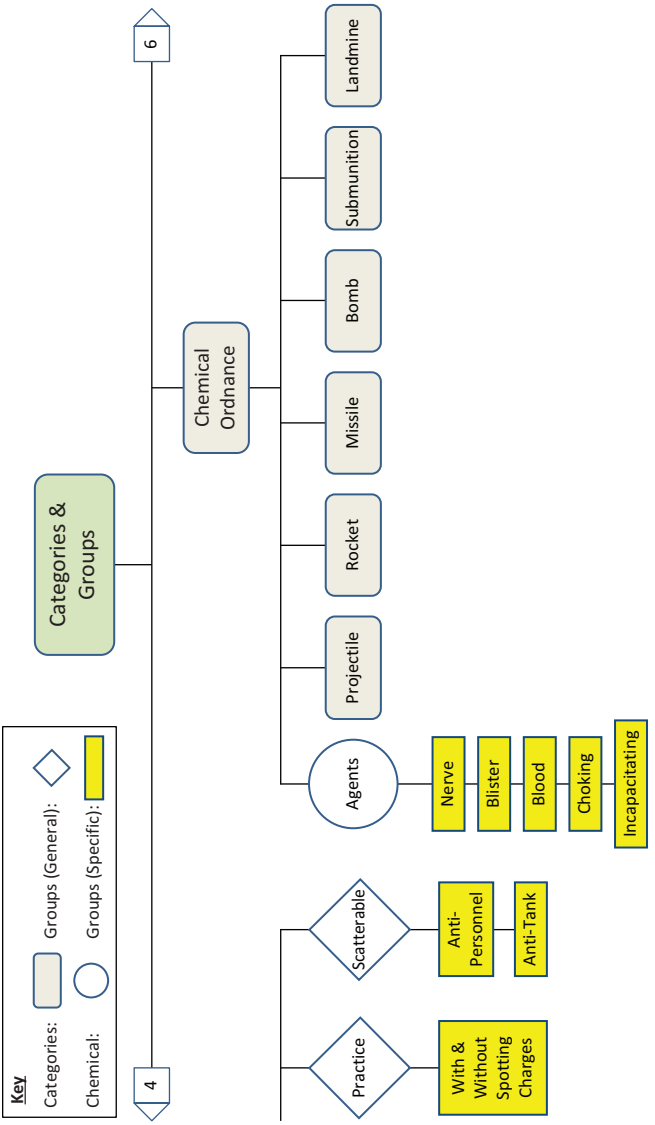
Logic Tree 2 – Categories and Groups

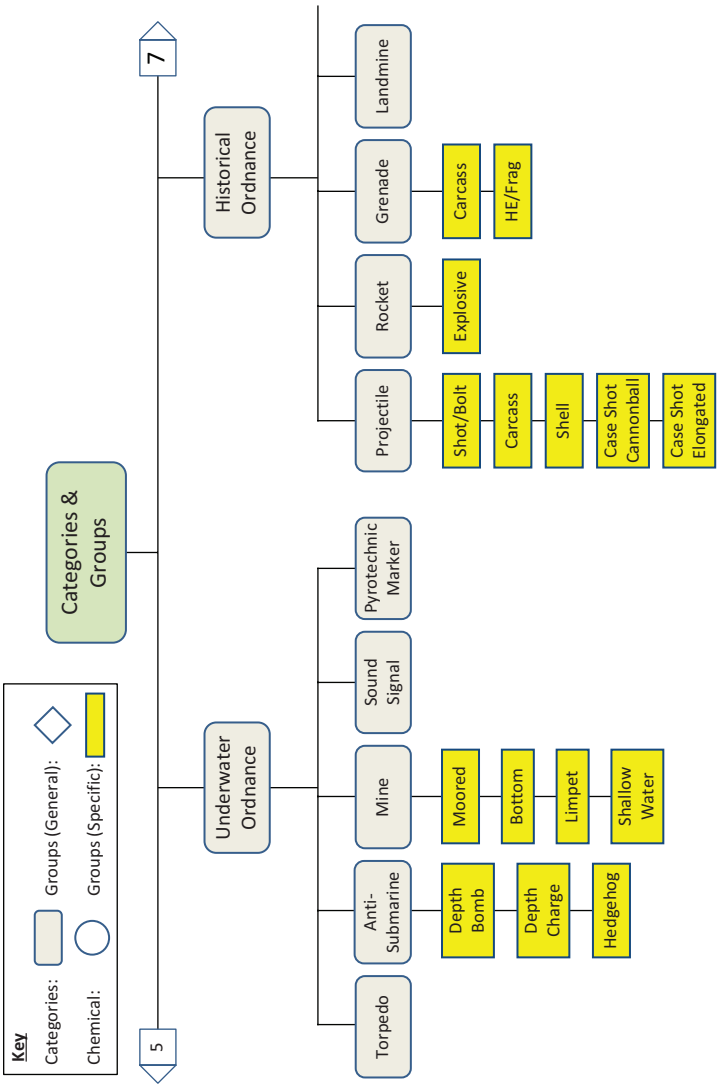


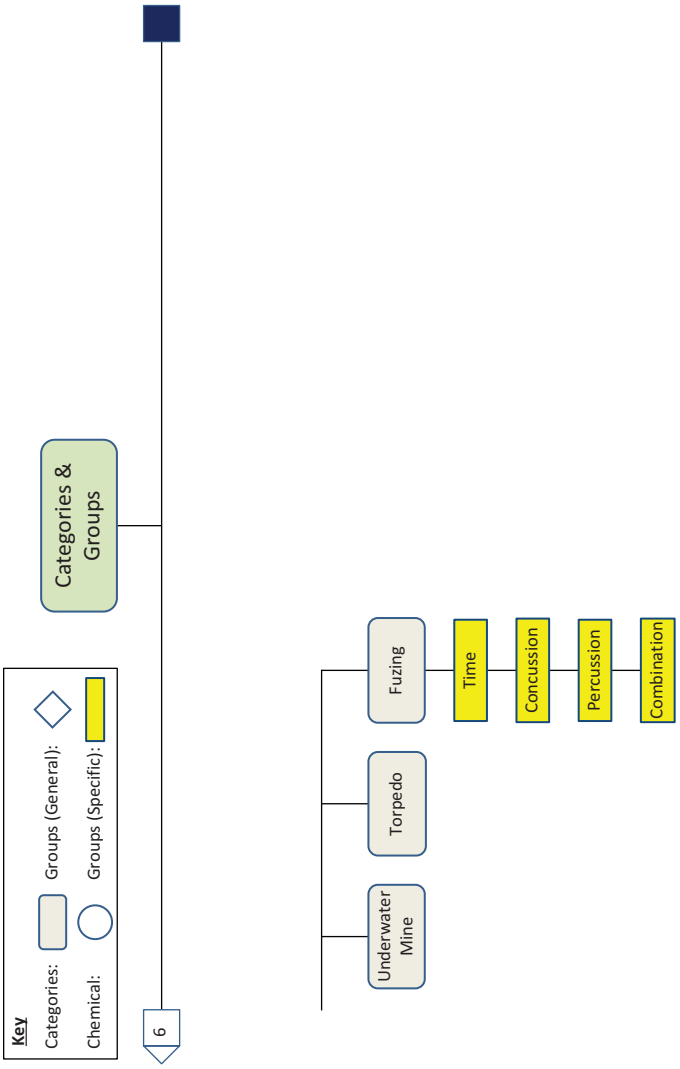

Key
Categories:
Groups (General):
Chemical:
Groups (Specific):
1
Categories & Groups
3
Rocket
High Explosive
HE/Frag
HE Bounding
Thermobaric & Incendiary
HEAT
Dispenser
Smoke
Bursting Smoke
Illumination
Practice
With & Without Spotting Charges
Drill & Dummy
Grenade
Hand Grenade
Blast
Frag
HEAT
Bursting Smoke/WP
Burning Smoke
Riot Control
Illumination
Incendiary
Practice
Rifle Grenade
Frag
HEAT
Bursting Smoke
Burning Smoke, Colored Smoke & Riot Control
Illumination
Practice
Projected Grenade
HE/Frag
HEDP
Bursting Smoke
Burning Smoke, Colored Smoke & Riot Control
Illumination
Practice


Key
Categories:
Groups (General):
Chemical:
Groups (Specific):
2
Guided Missile
High Explosive
HE/Frag
HEAT
Dispenser
Practice
With Active Components
Drill & Dummy
Categories & Groups
Bomb
High Explosive
Frag
GP Old
GP Low Drag
Demolition
Penetration
Guided
FAE
Fire
Photoflash
WP
Napalm
Incendiary
Practice
With Explosive or Spotting Charge
Inert Load
4

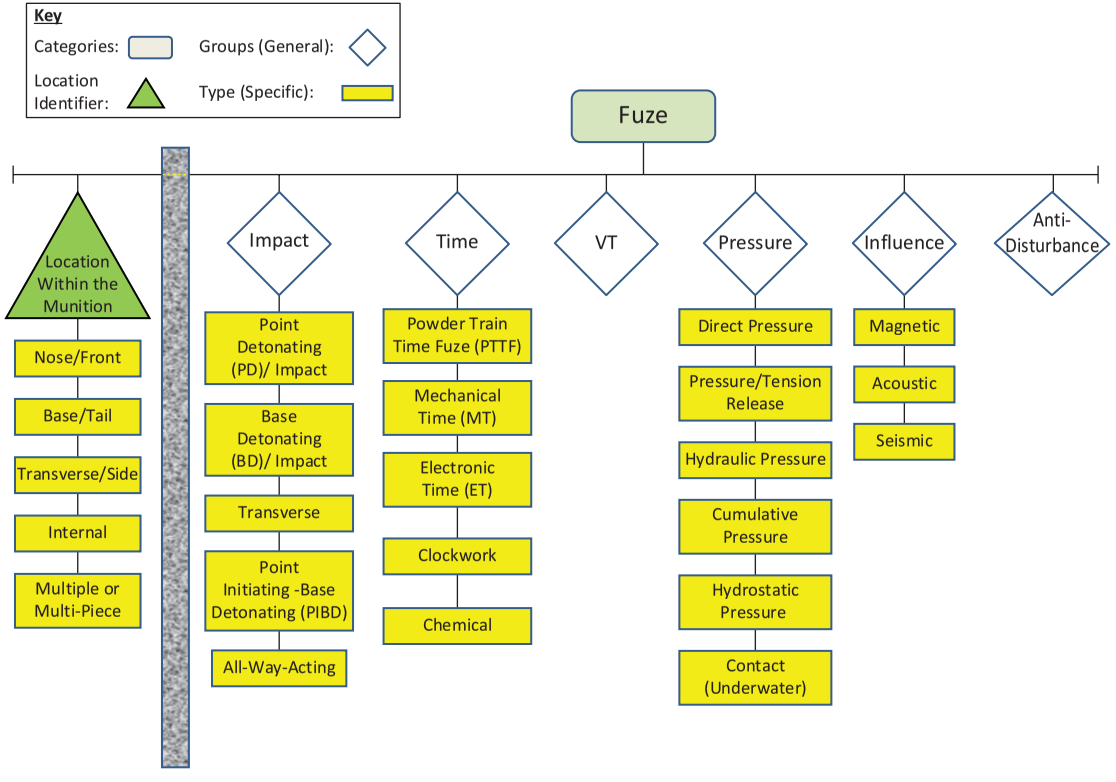

Key
Categories:
Groups (General):
Chemical:
Groups (Specific):
Categories & Groups
3
Dispenser (Air)
Retained
Dropped
Submunition
High Explosive
HE/Frag & HEI
HE Bounding
FAE
HEAT & EFP
Incendiary
Practice
With & Without Spotting Charges
5
Landmine
Anti-Personnel
Blast
HE/Frag
Bounding Fragmentation
Directional Fragmentation
Anti-Tank
Blast
Shaped Charge & EFP


Key
Categories:
Groups (General):
Chemical:
Groups (Specific):
4
Categories & Groups
6
Chemical Ordnance
Landmine
Submunition
Bomb
Missile
Rocket
Projectile
Agents
Nerve
Blister
Blood
Choking
Incapacitating
Scatterable
Anti-Personnel
Anti-Tank
Practice
With & Without Spotting Charges

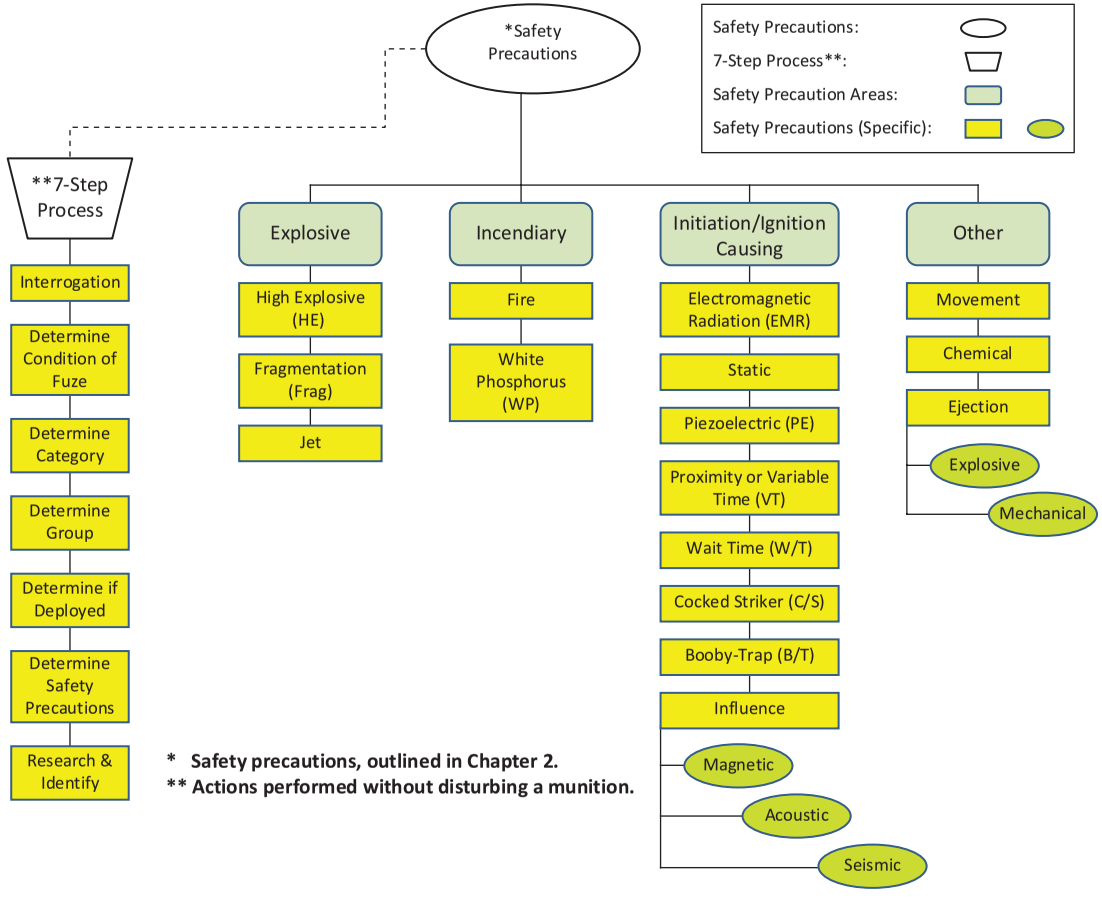

Key
Categories:
Groups (General):
Chemical:
Groups (Specific):
5
Categories & Groups
7
Underwater Ordnance
Torpedo
Anti-Submarine
Depth Bomb
Depth Charge
Hedgehog
Mine
Moored
Bottom
Limpet
Shallow Water
Sound Signal
Pyrotechnic Marker
Historical Ordnance
Projectile
Shot/Bolt
Carcass
Shell
Case Shot Cannonball
Case Shot Elongated
Rocket
Explosive
Grenade
Carcass
HE/Frag
Landmine


Key
Categories:
Groups (General):
Chemical:
Groups (Specific):
Categories & Groups
Underwater Mine
Torpedo
Fuzing
Time
Concussion
Percussion
Combination
6

Logic Tree 3 – Fuzes



Logic Tree 4 – Safety Precautions



Appendix B: U.S. Ordnance-Related Abbreviations, Markings, and Symbols

Every country uses different means to identify ordnance. As a starting point, many American and Russian abbreviations, markings, and symbols are provided. Similar information for other countries is available in Appendix F: References.

AA: Anti-Aircraft
AAA: Anti-Aircraft Artillery
AC: Hydrogen Cyanide
ACM: Anti-Armor Cluster Munition
ADAM: Area Denial Artillery Munition
AGM: Air Launched Surface Attack Missile
AIM: Air Intercept Missile
AN: Army/Navy, used to designate munitions approved for use by the Army and Navy
AP: Armor Piercing
APAM: Anti-Personnel Anti-Materiel munition
APC: Armor Piercing Capped
APDS: Armor Piercing Discarding Sabot
APERS: Anti-Personnel
APHE: Armor-Piercing High Explosive. An AP munition with a HE charge in the base
APHEI: Armor Piercing High Explosive Incendiary
AT: Anti-Tank
BD: Base Detonating or Bomb Disposal
BDU: Bomb Dummy Unit
BE: Base Ejecting
BGM: Multiple Platform Launched Surface Attack Missile
BLU: Bomb Live Unit
B/T: Boobytrap
CAD: Cartridge Actuated Device
CAS: Control Actuation System
CBU: Cluster Bomb Unit

CG: Phosgene, a chemical agent
CN: Chloroacetophenone, a tactical riot control agent
CS: 2-chlorobenzalmalononitrile or o-chlorobenzylidene malononitrile, tactical riot control agents
C/S: Cocked-striker
CWD: Conventional Weapons Destruction
EMR: Electromagnetic Radiation
EO: Explosive Ordnance
EOD: Explosive Ordnance Disposal
EOR: Explosive Ordnance Reconnaissance
ER: Extended Range (see RAP)
ERW: Explosive Remnants of War
ET: Electronic Time
FAE: Fuel Air Explosive
FASCAM: Family of Scatterable Mines
FIM: Individual Launched Air Intercept Missile
FGM: Individual Launched Surface Attack Missile
FM: Titanium Tetrachloride
FMU: Fuze Munition Unit
Frag: Fragmentation
FS: Sulphur Trioxidechlorosulfonic Acid Solution (white smoke)
GA: A nonpersistent nerve agent
GB: A nonpersistent nerve agent
GP: General Purpose
GPHD: General Purpose High Drag
GPLD: General Purpose Low Drag
GPNS: General Purpose New Style
GPOS: General Purpose Old Style
H: A mustard agent
HC: Hexachloroethane-zinc (white smoke)
HD: A distilled mustard agent
HE: High Explosive
HEAT: High Explosive Anti-Tank
HEDP: High Explosive Dual Purpose
HEI: High Explosive Incendiary
HEP: High Explosive Plastic (known as a "Squashhead" in some countries)
HERA: High Explosive Rocket Assist (see RAP)
HVAP: High Velocity Armor Piercing
HVAPDS: High Velocity Armor Piercing Discarding Sabot
ICM: Improved Conventional Munition
IED: Improvised Explosive Device
Illum: Illumination
IM: Insensitive Munitions

IMAS: International Mine Action Standards
IR: Infrared
JATO: Jet Assist Take Off
JET: Focused, high speed plasma cutter formed by a shaped charge
LE: Low Explosive
LUU: Illumination Unit
M: Model (designates model number on Army munitions)
MANPADS: Man Portable Air Defense System
MK: Mark (designates model number on Naval munitions)
MOD: Modified or modification
MSDS: Material Safety Data Sheet
MT: Mechanical Time
MTSQ: Mechanical Time Superquick
PAD: Propellant Actuated Device
PD: Point Detonating
PDSD: Point Detonating Self-Destruct
PDSQ: Point Detonating Superquick
PE: Piezoelectric Crystal
PI: Point Initiating
PIBD: Point Initiating Base Detonating
Projo: Projectile
Prox: Proximity (interchangeable with VT)
PSSM: Physical Security and Stockpile Management (for ordnance storage)
PTTF: Powder Train Time Fuze
PUCA: Pickup and Carry Away
PWP: Plasticized White Phosphorus
RAAM: Remote Anti-Armor Mine
RAP: Rocket Assisted Projectile (see HERA)
RP: Red Phosphorus
RPM: Revolutions Per Minute
RSP: Render Safe Procedure
S&A: Safe & Arm Device
SAM: Surface-to-Air Missile
SAP: Semi-Armor Piercing
SAPHE: Semi-Armor Piercing High Explosive
SAPHEI: Semi-Armor Piercing High Explosive Incendiary
SD: Self-Destruct
SQ: Superquick
SVD: Stable Velocity of Detonation
T: Tracer
TDD: Target Detection Device (component of VT or Influence fuzing)
TP: Target Practice
TSQ: Time Super-Quick

UXO: Unexploded Ordnance. A deployed munition that failed to function as designed
VD: Velocity of Detonation
VT: Variable Time (interchangeable with proximity)
VX: A persistent nerve agent
WP: White Phosphorus
WRA: Weapons Removal and Abatement
W/T: Wait-time

Appendix C: Functional Definitions for Ordnance-Related Terms

Adapter: A component used to facilitate a connection.

Adapter Booster: An adapter containing an explosive booster.

Anti-Materiel: The addition of magnesium, zirconium, and other metals to produce effects that damage or destroy materiels.

Anti-Personal (APERS): Ordnance designed to kill or wound personnel. Munitions designed to wound personnel and apply adverse psychological and logistical effects on an enemy.

Approach & Initial Interrogation: The initial approach, observation, examination, and documentation of a recovered munition or munitions. Step 1 of the Seven-Step practical process for identifying a munition (see Ordnance Recon).

Arming Delay: A mechanical, pyrotechnic, or electrical component that delays the arming sequence of a fuze.

Arming Device: An internal component designed to electrically or mechanically align the explosive train within a fuze. (See S&A Device).

Arming Pin, Safety Pin, Arming Clip, Arming Fork, or other Positive Safety: A device inserted into or around a fuzing component to provide a positive block.

Arming Vane: A propeller-like component that rotates when moving through an airstream or water (see Water Forces and Wind Forces).

Arming Wire: A wire attached to an aircraft at one end and a fuze at the other. When the munition is ejected from the aircraft, the arming wire is pulled and the arming sequence begins.

Armor-Piercing (AP): Ordnance designed to penetrate armor. May contain explosives, but kinetic penetrators do not.

Belleville Spring: A thin, round, concave shaped piece of metal or hard plastic with a hole or firing pin in its center. When the required pressure is applied the spring "snaps" through its concave center inverting its shape. Commonly used in anti-personnel landmine fuzes.

Body: The area of a projectile between the bourrelet and the rotating band; or, the primary component of an ordnance item. Often used interchangeably with the term "warhead."

Bomblet: A munition contained within or deployed from a dispenser. Bomblet usually refers to a munition from an aerial dispenser (see Submunition and Cluster Bomb).

Booby-trap (B/T): A device designed to be triggered when disturbed by an unsuspecting victim. When applied to landmines, submunitions, and other ordnance, the device is usually made to appear harmless, and the threat is usually an explosion.

Booster: The largest explosive component of a fuze.

Booster Adapter: A component, containing an explosive booster, used to facilitate a connection.

Bore-Riding Pin: A spring-loaded safety pin held in place within a fuze until the munition is fired and setback releases it. As the munition moves down the tube, the bore-riding-pin is held in place by the "bore" of the weapon system. Upon exiting the bore, the pin is ejected from the fuze allowing the arming sequence to complete.

Burn Rate: The rate at which gases are generated from a burning propellant, which is greatly affected by pressure and temperature.

Capacitor: An electrical component capable of storing electrical energy for one-time-use before recharging.

Cartridge: Refers to fixed and semi-fixed projectiles.

Centrifugal Force: An outward force exerted upon a spinning body. During firing and flight, centrifugal force stabilizes trajectory while moving fuze components to allow arming.

Cluster Bomb/Munition: A munition contained within, or deployed from, a dispenser (see Bomblet and Submunition).

Cocked Detonator: See cocked striker.

Cocked Firing Pin: See cocked striker.

Cocked Striker (C/S): A striker, firing pin, or detonator under spring tension, held in place by a positive block within the fuzing mechanism. During fuze functioning, the positive block should move, freeing the striker to function the fuze.

Conductor: A material that conducts electricity very well.

Contact: A term associated with underwater mine fuzing.

Creep: The slow "creep-forward" motion of internal fuze components caused by a loss of velocity. Creep can be used to arm or function a fuze (See Deceleration, Retardation, Set-Forward).

Creep Spring: A spring used to slow "creep" within components of a fuze during flight.

Deceleration: The gradual loss of velocity after a munition reaches the apex of its trajectory. Deceleration can be used to arm or function a fuze (See Creep, Retardation, Set-Forward).

Deflagration: A rapid burn that produces intense heat in the form of a fireball; a fuel rich explosion. Propellant and damaged ordnance is capable of deflagrating.

Demilitarization: A munition with all hazardous components removed, in which case it should be marked by proper authorities. Or a munition subjected to a destructive process leaving no doubt the munition no longer poses a threat.

Demining: The process of clearing minefields or areas known to contain landmines.

Density: The mass of a material in a specified volume.

Detent: A mechanical catch impeding or stopping the movement of fuzing components.

Detonation: A chemical reaction that propagates a self-sustaining shockwave and reaction zone that exceeds the speed of sound in the unreacted materiel (see VD and SVD).

Detonator: A component of a high explosive train; initiated by percussion, stab, electric, or flash insult. Capable of reliably initiating the next high explosive component in the train.

Detonator Safe: A safety feature describing a position the detonator can be in and not initiate the munition if it functions.

Direct or Manual Arming: The removal of a safety device, such as a safety pin or clip that partially or completely arms a munition. Common on landmines and grenades.

Dispenser: A munition designed to dispense submunitions, bomblets, and cluster bombs/munitions.

Drill Munition: A manufactured inert munition used for training or display (see Inert and Dummy).

Dud Fired: A deployed munition that failed to function as designed (see UXO).

Dummy: A manufactured inert munition used for training or display (see Inert and Drill Munition).

Electrical Impulse: When applied to ordnance—A surge of electrical power provided by a launch platform, an internal generator, or a piezoelectric crystal.

Explosive Train: Alignment of the explosive components, arranged in order of decreasing sensitivity and increasing strength.

Explosive Remnants of War (ERW): A term used to describe an explosive filled Remnant of War (see Remnant of War).

Exploder: Fuzing most commonly associated with underwater ordnance.

Energy: The ability to do work.

Escapement Device: A mechanical device that regulates the rate at which fuzing components are unlocked or moved.

Explosive Bellows: Extend when expanding gases from a small explosive charge fill the bellow. These are used to complete electric circuits within some fuzes.

Firing Mechanism: A decision-making component present in some fuzes. Usually associated with influence fuzing and other underwater fuzing systems.

Firing Pin: A pin used to strike a primer or detonator in or on a munition.

Flat-Surface Concept: Explosive energy is consistently focused when applied against flat surfaces (see Munroe Effect in Chapter 1).

Force: An effect capable of changing the speed or direction of a body in motion.

Function as Designed: The term used to define when or how a munition functions correctly, producing the designed effect.

Fumer: The introduction of gas at a specific rate that fills the partial void created behind a projectile in flight. Disrupting the vacuum and reducing drag, greatly increases range.

Fuse: A length of tube or cord-like material filled with black powder. Commonly referred to as time-fuse and used for non-electrical explosives work. Also, an older term used to describe ordnance fuzing (see fuze).

Fuze: A mechanical or electrical device used to initiate ordnance. For pre-1900 ordnance, usually referred to as a "fuse" in reference literature (see Fuse).

Gravity: The force ensuring all ordnance will eventually end up on the ground or in the water.

Graze Sensitive: A design feature that affords a fuze the ability to function as designed when a grazing impact is made with a target. Once armed, fuzes containing this characteristic are extremely sensitive.

Guide Pin: A fixed pin used to guide a movable component within a fuze.

High Explosive Anti-Tank (HEAT): An HE munition with a shaped charge that may or may not include substantial fragmentation.

High Explosive Dual Purpose (HEDP): An HE munition with a shaped charge and substantial fragmentation.

High Order Detonation: When a High Explosive (HE) main charge is correctly initiated, reaches its SVD, and functions as designed (see Low Order, SVD, and VD).

Hydrostatics: Fluid pressure.

Hygroscopicity: The absorption properties of a material through airborne exposure or submersion. The introduction of moisture may affect the sensitivity or stability characteristics of an energetic materiel.

Improvised Ordnance (homemade): Incorporates locally available raw materiels and fabrication methods, with conventional ordnance designs and components.

Inert: A munition that contains no hazardous components.

Inertia: The forward motion of fuze components caused by the violent deceleration, or impact with a target. Inertia and creep differ only by the speed at which the ordnance slows.

Inertia Switch: A switch within a fuze that moves upon the violent deceleration of retardation, to complete a step in the arming sequence (see Retardation).

Influence: A term used to describe magnetic, acoustic, and seismic fuzing.

Insulator: A material with extremely high resistance to electrical conductivity.

Lead: Used to transfer explosive energy from one component in a fuze to the next (see Relay).

Low Order Detonation: Is when an initiated explosive fails to reach its potential energy output. The results can include explosive materiel that partially detonated, burned, or broke into pieces scattering the area. Causes include, but limited to, under strength or defective initiator, deteriorated or damaged explosives, improper explosive geometry, or chemistry (see High Order, SVD, and VD).

Luminous Intensity: Is the amount of light produced by a pyrotechnic composition. Usually expressed in "candlepower."

Magnetism: Force exerted by a magnetic field.

Mass: The amount of matter in an object.

Matter: Anything that has mass and occupies space. The three states of matter are solid, liquid, and gas.

Minefield: An area in which landmines or waterborne mines were purposefully deployed.

Motion The movement of a body. Motion implies that something has moved or changed position. Types of motion include:

- Acceleration and Deceleration: Change in an object's speed.
- Centrifugal Force: Forces a body to move away from the center of a rotating object.
- Velocity: Distance covered in a given time.

Motion: Newton's 1st Law of Motion: Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.

Motion: Newton's 2nd Law of Motion: The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.

Meaning, the acceleration of an object is dependent upon two variables, (1) the force acting on the object and (2) the mass of the object.

Motion: Newton's 3rd Law of Motion: For every action, there is an equal and opposite reaction.

Munition: A military ordnance item or single piece of ammunition. Used interchangeably with "Ordnance" (see Ordnance).

Ordnance: A military munition or multiple munitions. Used interchangeably with "Munition" (see Munition).

Ordnance Recon: The initial approach, observation, examination, and documentation of a recovered munition or munitions (see Approach & Initial Interrogation).

Pyrotechnic Delay: A pressed black powder train ignited during firing or deployment. Used to initiate the next action within a munition after burning for a predetermined time. Can be used as the primary means of arming and functioning a fuze, or as a secondary means of functioning such as a self-destruct.

Primer: Used to initiate a pyropellent. May also be used to initiate a detonator.

Power Cell (Primary): Non-rechargeable power sources, such as galvanic, voltaic and dry cells.

Power Cell (Secondary): Rechargeable power sources, such as Nickel-Cadmium and lead acid cells.

Piezoelectric (PE) Crystals: A quartz crystal that produces an electrical impulse when stressed. PE fuzing systems use a quartz crystal to produce electric current when impacted or otherwise stressed. The current produced by the PE crystal is used to arm or function munition components, such as initiating an electric detonator in the fuze. PE fuzes can retain their ability to function indefinitely, are considered extremely hazardous, and can cause the unintentional initiation of munition. Damaged ordnance is especially vulnerable to EMR and static.

Relay: Used to delay or amplify the transfer of explosive energy from one component in a fuze to the next (see Lead).

Radome: The outer shell of VT fuzing that encloses an antenna or electronics package. Radomes are usually made of plastic or other materials that do not block energy passing through.

Rotor: A disk or ball shaped component of a fuze that turns or rotates during the arming sequence. Rotors usually contain a detonator.

Ram: Air An opening that allows high speed air to enter a component of a munition.

Remnants of War (RW): A munition, or recognizable component of a munition, that was located in, or removed from, an area of conflict. Also referred to as "War Trophies," RW are often UXO or contain other dangerous materiels.

Retardation: The sudden and violent deceleration from the opening shock of parachute or snakeye fin assemblies, also called Retardation Devices

and high-drag producing fins. Retardation is used to arm some fuzes (See Deceleration, Set-Forward, Creep).

Render Safe Procedure (RSP): An EOD procedure used to interrupt the function of a fuze or separate essential components of a munition to prevent it from Functioning as Designed. Access to U.S. EOD 60-Series publications is required to research and determine the appropriate RSP for a munition.

Research: Performed to address Step 7 of the practical process for identifying a munition.

Semi-conductor: Material between the extremes of a conductor and an insulator. Examples include silicon, germanium and carbon.

Setback: During firing or launch, acceleration causes movable components in a fuze to move backwards, or "setback."

Setback Pin and Spring: A pin held in place by a spring. Upon firing, setback moves the pin rearward compressing the spring. The fuze arming sequence may use this action to allow other components to move.

Slider: A fuze component that "slides" into position during the arming sequence. Sliders usually contain a detonator.

Super Quick and Delay Selectors: An external component resembling a standard screw that allows a fuze to function in different modes (not present on all fuzes).

Spitback: A term used to describe a 2-section fuzing configuration in which one section initiates the second by "spitting back" an explosive impulse through a tube or void within the munition. Commonly used with HEAT and Shrapnel munitions.

Set-Forward: The sudden deceleration from the opening shock of parachute or snakeye fin assemblies. Set-Forward can be used to arm or function a fuze (See Deceleration, Retardation, Creep).

Safe & Arming (S&A) Device: An arming device designed for more complex fuzing systems, it electrically or mechanically aligns components for proper initiation while safeguarding against unintentional functioning of the munition.

Self-Destruct Feature: A pyrotechnic, electrical or mechanical feature designed to function a fuze after a pre-determined amount of time.

Self-Neutralization Feature: A device or element within a munition that renders it inoperative. It does not make the munition safe to handle.

Sympathetic Detonation: A detonation caused by the transmission of a shock wave from one high explosive, through a medium such as the body of an ordnance item, into a second high explosive materiel resulting in a high order detonation.

Submunition: A munition contained within or deployed from a dispenser (see Bomblet and Cluster Bomb).

Stable Velocity of Detonation (SVD): The speed at which the reaction zone progresses through the explosive without diminishing in strength. Each explosive materiel has an SVD range based on factors including density, temperature, geometry and method of initiation.

Standoff Spike: An ogive configuration with a spike-like appearance, designed to provide the required standoff distance for a shaped charge warhead to function correctly (see HEAT

Thermal Battery: Single use, high temperature galvanic cell. Contain a metallic salt electrolyte, activated by a pyrotechnic charge to provide a lot of power for a short period of time. Due to high costs, are used primarily on missiles and underwater ordnance (see Power Cell, Primary).

Unexploded Ordnance (UXO): A deployed munition that failed to Function as Designed (see Dud Fired).

Velocity of Detonation (VOD): The initial speed at which the reaction zone travels through the explosive materiel (see Detonation and Stable Velocity of Detonation).

Warhead: The section of a munition that contains chemical agents, high explosives, or other energetic materiels. Oftentimes used interchangeably with the term "body," but warhead is more commonly associated with missiles and rockets

Water Forces: The force exerted by water on a munition, or on components as a munition travels during deployment (see Arming Vane).

Wind Forces: The force exerted by air flow as a munition travels during deployment (see Arming Vane).

Appendix D: Explosives with U.S. and Russian Reference Charts

Every country uses a variety of explosives in the ordnance they manufacture, and the number of small alterations is endless. For example, the addition of aluminum or other materials to an explosive will change the characteristics as well as the name. Due to the vast number of possible compositions, examples of a few of the Primary, Secondary, and Main Charge explosives often found in ordnance produced by many countries is offered.

Primary Explosives

Are the least powerful, but most sensitive of the three groups. Characteristics include:

1. Detonate when exposed to flame in confined or unconfined configurations.
2. Very sensitive to initiation from heat static discharge.
3. Very sensitive to initiation from impact, such as a strike from a firing pin.

Examples of primary explosives include:

Lead Azide: A very common primary explosive in modern ordnance.

- Color ranges from white-buff to gray.
- Velocity of Detonation (VOD) is 14,800 fps (4,500 mps) @3.8g/cm^3 (at 3.8 grams per cubic centimeter).
- Moderately hygroscopic.
- Reacts with copper to form extremely sensitive cupric azide. For this reason, it is usually loaded in aluminum housings.

Other names include: Lead Hydronitride (United States), Azoture de Plomb (France), Bleiazid (Germany), Chikka Namari (Japan), and Acido di Pimbo (Italy).

Lead Styphnate: A very common primary explosive in use since WW1.

- Color ranges from yellow, orange to reddish brown.

- VOD is 17,000 fps (5,200 mps) @2.9g/cm^3.
- Slightly hygroscopic.

Other names include: Trinitrorescorcinate de Plomb (France).

Mercury Fulminate: Widely used in ordnance until replaced by lead azide and lead styphnate.

- Color ranges from white, light brown, to light yellow.
- VOD is 16,400 fps (5,000 mps) @3.3g/cm^3.
- Nonhygroscopic.
- Reacts with aluminum, magnesium, copper, zinc, and brass.

Other names include: Fulminate of Mercury (U.S.), Fulminate de Mercure (France), Knallquecksilber (Germany), Fulminato di Mercurio (Italy), Rtutnyy ful'minat (Russia), and Raisanuigin (Japan).

Secondary Explosives

Are usually mixed to make main charge explosives. Characteristics include:

1. Not as sensitive to heat, shock, or friction as primaries, and usually burn when unconfined. As a dust they are susceptible to exploding if exposed to static discharge.
2. Provide enough energy to reliably initiate main charge explosives.
3. Used between primary and main charge explosives as boosters, leads, relays, and other fuzing components.

Examples of secondary explosives include:

TNT: For military applications, TNT and RDX are the two most commonly used explosives. Discovered in 1863, Germany was the first country to adopt TNT for ordnance applications in 1902. The energetic properties of TNT are the standard by which other explosives are measured. When characterizing an explosive material, TNT is used as the baseline = 1.

- Colors range from light brown, to slightly yellowish.
- VOD is 22,600 fps (6,900 mps) @ 1.60g/cm^3.
- Nonhygroscopic.
- Reacts with ammonia, sodium hydroxide, sodium carbonate, and other alkalies to form extremely sensitive compounds.

Other names include: Trinitrotoluene (chemical name), Trotyl (UK), Tolite (France), Fullpulver 02 and Sprengmunition 02 (Germany), Chakatusuyaku (Japan), Tritolo (Italy).

Note: Explosives containing a high percentage of TNT include: Amatol, Ammonal, Ammonite, Baratol, Baronal, Boracitol, Cheddite (some receipts), Composition B, Cyclotol, Ednatol, H-6, Hexanite, HBX, Octol, PBXN, Picratol, Plumbatol, PTX, Tetrytol, Torpex, and Tritonal to name a few.

Tetryl: Invented in 1877, Tetryl was expensive to make and costs led to a constant search for cheaper means of manufacturing, until it was replaced by RDX and HMX.

- Color is yellow, but graphite is commonly added turning it gray.
- VOD is approximately 24,800 fps (7,570 mps) @ 1.71g/cm^3.
- Slightly hygroscopic.
- Reacts slightly with zinc, iron, and brass.

Other names include: 2,4,6-trinitrophenylmethylnitramine (chemical name), Composition Exploding "CE" (UK), and Tetra (Germany).

RDX: For military applications, RDX and TNT are the two most commonly used explosives. However, RDX is almost 50% more brisant and 75% more powerful than TNT. Discovered in Germany in 1899, RDX was not used extensively in ordnance until WWII.

- Color is white.
- VOD is 24,000 fps (7,300 mps) @ 1.49 g/cm^3.
- Nonhygroscopic.

Other names include: Cyclotrimethylenetrinitramine (chemical name), Cyclonite (UK), Exogen (France), Hexogen (Russia), Shouyakuand (Japan), T4 (Italy).

Note: Explosives containing a high percentage of RDX include: CH-6, Compositions A, A-2, A-3, A-4, and A-5, Composition B, Compositions C, C-2, C-3 and C-4, Cyclotol, A-IX-I (A-91), A-IX-II, (A-92), DBX, H-6, HBX, MOX, Nitronafita, PBX, PBXN, PBXW (Teflon), PTX, Torpex, to name a few.

HMX: An extremely brisant explosive. It is not used in pure form, but rather mixed with other explosives and desensitizers.

- Color is white.
- VOD is approximately 29,800 fps (9,100 mps) @ 1.9 gm/cm^3.
- Non-hygroscopic.

Other names: Cyclotetramethylenetetranitramine (chemical name), Octogen (Germany), Okfol (Russia), Octogere (France), and Octol (U.S.).

Note: Explosives containing a high percentage of HMX include: HTA-3, LX, PBX, and PBXN.

Picric Acid: Used extensively by Japan, Germany, and other countries during WWII. Today, it is used by many countries as the explosive characteristics are very similar to TNT.

- Color is yellow.
- VOD is approximately 23,000 fps (7,000 mps).
- Slightly hygroscopic.
- Reactivity: Excluding aluminum and tin, reacts with all metals to form extremely sensitive compounds called picrates.

Other names include: Trinitrophenol (chemical name), Melinite (French), Lyddite (UK), Granatfullung 88 (Germany), Ercasite (Austria), Pertite, (Italy), Ooshokuyaku or Shimose (Japan), Coronite (Sweden), Picrinite (Spain), and Melinit or M (Russia).

Main Charge and Bursting Charge Explosives

Typical main charge explosives are a combination of secondary explosives and other materials designed to produce specific energy output characteristics. A main charge can consist of a single explosive such as cast or pressed TNT, but explosive blends are more common, and VODs vary depending on the mixture ratios. Examples of main change explosives include:

Amatol: A mixture of ammonium nitrate and TNT ranging from an 80/20 to 40/60 mix. The mixture is reflected in the markings; for example, 80/20 Amatol consists of 80% ammonium nitrate and 20% TNT.

- Colors range from yellow to brown.
- VOD is approximately 15,000 and 21,000 fps (4,550 to 6,400 mps).
- Very hygroscopic.
- Reacts with copper, brass, and bronze to form sensitive compounds.

Other names include: Schneiderite (French), Fullpulver (Germany), Amotolo (Italy), Shotoyaku (Japan).

Explosive D: An exceptionally insensitive explosive used with ordnance designed to withstand tremendous impact before functioning after a delay. Primarily utilized in armor and concrete piercing munitions.

- Color is orange to reddish brown.
- VOD is approximately 23,000 fps (7,000 mps).
- Moderately hygroscopic.
- Reactivity: If moist, will react with lead, steel, copper, zinc, and bronze to form sensitive compounds.

Other names include: Ammonium Picrate (chemical name), Pikurinsan Ammonia (Japan), Dunnite (UK), Pikrinovokislyi Ammonii (Russia).

Composition B: One of the most powerful, multi-use explosives used by most countries. Made by combining RDX and TNT, it is marked in many different ways. American mixtures range from 70/30 to 50/50 all of which are identified as Comp B. In Russia, this is expressed as TD and a number such as TD-40; translates as T = TNT, D = DNN, and 40 is the percentage of TNT in the mixture. A simplistic identifier used by many countries is RDX/TNT or TNT/RDX with the most prominent explosive written first.

- Colors range from tan to brown.
- VOD is approximately 25,000 fps (7,600 mps).
- Nonhygroscopic.

Other names include: TG-30, TG-40, TG-50 (Russia).

H-6: Consists of 45% RDX, 30% TNT, and 20% aluminum powder and 5% wax. Developed to produce high blast effects and commonly used in underwater ordnance.

- Color is gray to silverish.
- VOD is approximately 23,600 fps (7,200 mps).
- Nonhygroscopic.
- Reactivity: When wet, it reacts with all metals except aluminum and stainless steel.

Other names: None.

Pentolite: Developed during WWII, Pentolite consists of 49% PETN, 49% TNT, and 2% wax to bind and desensitize. In pure form, PETN is as sensitive as a primary explosive and thus not often found in ordnance. When desensitized with TNT and wax to make Pentolite, it is an effective booster charge, and also finds limited use as a main charge.

- Color can be white, yellow, or gray.
- VOD is approximately 24,600 fps (7,500 mps).
- Nonhygroscopic.

Other names: Pentol (Germany), Pentritol (Italy).

Other Explosives

Throughout history, a countless number of explosives have been designed, developed, and tested for military applications. Some have been used extensively, while others are unsuitable for use in ordnance. Unfortunately,

significant shortcomings or unacceptable complications were sometimes found after widespread distribution and deployment.

Cheddites and DNN offer examples of flexibility and cost considerations in ordnance fillers from the early 1900s through today.

Cheddite: Classified as "Cheddites," the name of this explosive can mean many different things.

Today, Cheddite is not a first or second choice for ordnance applications, but in the early 1900s it was very popular and used by most countries. With so many countries using different resources available to them, the variations in materials and receipts is endless. Cheddite receipts include, but are not limited to, potassium chlorate, sodium chlorate, sodium nitrate, ammonium perchlorate, mononitronaphthalene, nitronaphthalene, dinitrotoluene (DNT), TNT, sawdust, castor oil, and paraffin; all of which result in different compositions with varying speeds and energy outputs.

- Color is commonly white or yellow.
- VOD is approximately 10,000 to 12,000 fps (3,000 to 3,700 mps).
- Hygroscopicity varies with different constituents.

Other names include: Blastine (UK), Sauranite (France), Alkasit or Parammon (Germany), Victorite or Cannel (Italy), Territ (Sweden), and Almatrit No.19 or Ammonalmatrit No.98 or Kaliialmatrit No.55 (Russia).

DNN: An inexpensive and weak explosive used by many countries in different ways. For example, France, Russia, and Italy used a mixture of one-part DNN to seven-parts ammonium nitrate in artillery projectiles during WWI.

Today, China fills many 82mm and 100mm projectiles with DNN and Russia mixes DNN with TNT to make TD explosives. Translated, TD- and a number, such as TD-40, translates T = TNT, D = DNN, and 40 is the percentage of TNT in the mixture.

- Color varies from white to gray.
- VOD is approximately 10,000 to 18,000 fps (3,000 to 5,500 mps).
- Hygroscopic.

Other names: Dinitronaphthalene (chemical name).

Reference Charts:

Examples of materials used by the United States and Russia. Though only a small sample, these lists bring to light the fact that different countries use similar materials in the ordnance they manufacture.

Examples of Russian Explosives Designations

Russian Designation	Translation	Explosive	Common Application
A-IX-1 (A-91)	Comp A	95% RDX, 5% wax	Small HE & HEAT munitions
A-IX-2 (A-92)		73% RDX, 23% AN, 4% wax	Medium HE munitions
A-40	Amatol	60% TNT, 40% AN	HE munitions
Д	DNN	Dinitronaphthalene (DNN)	HE munitions
ДБ	Dinitrobenzol	Dinitrobenzol	ID only
ДБТ	DB & TNT	Dinitrobenzene (DB) and TNT	HE munitions
Г	G	RDX (Hexogen)	HE munitions
К-1	TNT & DB	70% TNT, 30% DB	HE munitions
М	Picric Acid	Picric Acid, Melinit	HE munitions, WWI
ОКТОГЕН	HMX	HMX	HEAT munitions
ОКФОЛ		95% HMX, 5% wax	HEAT munitions
ОКТОЛ	Octol	70% HMX, 30% TNT	HEAT munitions
Т	TNT	Trinitrotoluene	HE munitions
ТГ-30	TG-30	30% TNT, 70% RDX	HE munitions
ТГ-50	TG-50	50% TNT, 50% RDX	HE munitions
ТД-50	TD-50	50% TNT, 50% DNN	HE munitions
ТД 42	TD-42	42% TNT, 58% DNN	HE munitions
ТГАФ-5	H6	TNT, RDX, AL	HE munitions
ТДУ	TNT, spotter	TNT and Spotting Smoke Charge	HE munitions

Examples of U.S. Explosives Designations

Designation	Mixture	Used in
Amatol 80/20	80% AN, 20% TNT	HE munitions
Ammonal	67% TNT, 22% AN, 11% AL	HE munitions
AN	Ammonium Nitrate	Various munitions
Composition A-3	91% RDX, 9% Wax	HE munitions
Composition B	60% RDX, 39% TNT, 1% Wax	HE munitions
Cyclotol 70/30	70% RDX, 30% TNT	HE munitions
DATNB	40% TNT, 21% RDX, 21% AN, 18% AL	HE munitions
Flare composition	58% Magnesium, 38% Sodium nitrate, 4% Binders	Flares
HBX-3	35% AL, 31% RDX, 29% TNT, 5% Wax	Underwater ordnance
HMX		HEAT munitions
LX-04-1	85% HMX, 15% Viton	HEAT munitions
Minol-2	40% TNT, 40% AN, 20% AL	HE munitions

(*Continued*)

(Continued)

Designation	Mixture	Used in
PBX-9011	90% HMX, 10% Estane	HEAT munitions
PBX-9205	92% RDX, 8% Binders	HEAT munitions
PBXN-3	86% HMX, 14% Binders	HE munitions
PBXN-104	70% HMX, 30% Binders	HE munitions
Photoflash Powder	60% Potassium perchlorate, 40% AL	Surveillance aircraft
Tetrytol 80/20	80% Tetryl, 20% TNT	HE munitions
Torpex	42% RDX, 40% TNT, 18% AL	Underwater ordnance
Tracer Composition	55% MG, 40% PTFE, 5% Viton	Tracer elements
Tritonal 80/20	80% TNT, 20% AL	HE Bombs
Green Flare Composition	42% MG, 27% Potassium Perchlorate, 17% Barium Nitrate, 14% Binders	Flares
Yellow Flare Composition	48% Sodium Nitrate, 44% MG, 8% Binder	Flares

U.S. Insensitive High Explosives (IHE) Designations

Outside military circles, little is known about the Insensitive High Explosives (IHE) being used in many munitions made today. In the U.S. each service classifies the IHE differently.

Naval Classifications: How the material is loaded.

PBX-1 through PBX-99 = Pressed Loaded
PBX-100 through PBX-199 = Cast Loaded
PBX-200 through PBX-299 = Extruded
PBX-300 through PBX-399 = Injection Molded

Army Classifications: Development status and method of loading.
Example: PAX-1A Type-1 P-D

PAX = Picatinny Arsenal Explosive.
1 = Sequence Number.
A = Indicates a small change in the composition.
Type-1 = Indicates further ingredient changes during and after initial development.
P = indicates loading method:
P (Press Loaded).
M (Melt Poured).
C (Cast Cured)
E (Extrusion Loaded).
I (Injection Loaded).

D = Indicates the status of the compound:
D (developmental).
Q (Qualified).
F (Final).

Air Force Classifications: The explosive compound.
Prefix for Air Force Explosive: AFX-_____

AFX 100 = RDX Based.
AFX 200 = HMX Based.
AFX 300 = PETN Based.
AFX 400 = Intermolecular
AFX 500-550 = DATB, TPM, PYX (Non-Metallized).
AFX 551-500 = DATB, TPM, PYX (Metallized).
AFX 600 = Heterocyclic (e.g., NTO, TNAZ).
AFX 700 = Aluminized RDX.
AFX 800 = Aluminized HMX.
AFX 900 = Nitroguanidine based or contains Nitroguanidine.
AFX 1000 = Explosive foam.
AFX 1100 = TNT Based.
AFX 1200 = High-density (heavy metal loaded, e.g., Tungsten, Tantalum, and Zirconium).
AFX 1400 = Formulations with Nano-ingredients.

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Appendix E: U.S. and Russian Ordnance Marking Schemes

Every country has different means of marking the ordnance they manufacture and the correct key must be used when interpreting these markings. As a starting point, examples of American and Russian abbreviations, markings, and symbols are provided. Similar information for other countries can be found in the bibliography.

The U.S. BGM-71, TOW missile is provided as an example of interpreting U.S. missile and rocket naming designations. After defining the launch environment, mission and vehicle designation, the vehicle designation number "71" is the sequential number for that munition within that vehicle type. If the munition is not experimental or in a test-phase, the Status Prefix information is not provided. Similar information on missile and rocket designators for each country can be found in the references provided in Appendix F and online.

B = Launch Environment.
G = Mission.
M = Vehicle Designation.
71 = Vehicle designation number.

Naming Designations

Status Prefix		Launch Environment		Mission		Vehicle Designation	
C	Captive	**A**	Air	**C**	Transport	**B**	Booster
D	Dummy	**B**	Multiple	**D**	Decoy	**M**	Guided Missile
J	Special Test (temporary)	**C**	Coffin	**E**	Electronic/Communications	**N**	Probe
N	Special Test (permanent)	**F**	Individual	**G**	Surface Attack	**R**	Rocket
X	Experimental	**G**	Surface	**I**	Aerial/Space Intercept	**S**	Satellite
Y	Prototype	**H**	Silo Stored	**L**	Launch Detection/Surveillance		
Z	Planning	**L**	Silo Launched	**M**	Scientific/Calibration		
		M	Mobile	**N**	Navigation		
		P	Soft Pad	**Q**	Drone		
		R	Ship	**S**	Space Support		
		S	Space	**T**	Training		
		U	Underwater	**U**	Underwater Attack		
				W	Weather		

U.S./NATO Color Codes and Marking

Ammunition	Body	Markings	Bands
HE, except 20mm	Olive Drab	Yellow	Yellow
HE, 20mm	Yellow	Black	None
Munitions with binary explosives	Olive Drab	Yellow	Broken Yellow
HEP	Olive Drab	Yellow	Black
HEAT	Black	Yellow	None
APERS and AT mines	Olive Drab	Yellow	Yellow
Incendiary	Light Red	Black	None
HEI	Yellow	Black	Light Red
API	Black	White	Light Red
AP			
With Bursting Charge	Black	Yellow	None
Without Bursting Charge	Black	White	None
Cannister	Olive Drab	White	None
Flechette Loaded	Olive Drab	White	White
Chemical			
Filled with toxic chemical binary	Gray	Dark Green	Broken Dark Green
Nerve Agent			Dark Green
Riot Control Agent	Gray	Red	Dark Green
Incapacitating Agent	Gray	Violet/purple	Dark Green
Toxic Chemical Agent	Gray	Dark Green	
Illuminating			
Separate Loading	Olive Drab	White	White
Fixed or Semi Fixed	White	Black	None
Practice			
With Low Explosives			Brown
With High Explosives			Yellow
Without Explosives			None
Smoke Ammunition	Light Green	Black	None
WP Smoke Ammunition	Light Green	Light Red	Yellow

Russian Ordnance Abbreviations, with English Translation

Cyrillic	English	Meaning
А	A	Propaganda or Fragmentation
Д	D	Smoke
ДЦ	DTs	Target Marker Smoke
Ф	F	High Explosive (F = Fugasnyj)

(*Continued*)

(Continued)

Cyrillic	English	Meaning
Г	G	Concrete Piercing
О	O	Fragmentation (O = Oskolochno)
ОФ	OF	Fragmentation High Explosives
ОГ	OG	Fragmentation (projected grenades)
ОФР	OFR	Fragmentation High Explosive Tracer
ОФЗТ	OFZT	High Explosive Incendiary Tracer (improved)
ОСКОК	Frag	Fragmentation
ОР	OR	Fragmentation Tracer
ОЗ	OZ	Fragmentation Incendiary
ОХ	OKh	Fragmentation Gas
ПБР	PBR	Armor Piercing Target Practice
З	Z	Incendiary
Р	R	Tracer
ПРАКТ	Prac	Practice
ПУ	PU	Target Practice
Г	G	Concrete Piercing
С	S	Illumination
Ш	Sh	Shrapnel
Щ	Shch	Canister
Б	B	Armor-Piercing
Х	Kh	Gas, Chemical
ИНЕRТ	INERT	Inert
МАКЕТ	Make	Model
БР	BR	Armor-Piercing, Tracer
БЗ	BZ	Armor-Piercing, Incendiary
БЗА	BZA	Armor-Piercing, Incendiary (improved)
БЗР	BZR	Armor-Piercing, Incendiary, Tracer
БМ	BM	Armor-Piercing, Discarding Sabot
СП	SP	Armor Piercing, Solid Shot
БП	BP	HEAT, Spin Stabilized
БК	BK	HEAT, Fin Stabilized
ПГ	PG	HEAT
РПО	RPO	Infantry Flame Weapon
МУВ	MUV	Fuze, Pull
МВ or МВЗ	MV or MVZ	Fuze, Pressure
ВПФ	VMF	Fuze, All Ways Acting
ЭХЗ	EKhZ	Fuze, Electric Chemical
ЧЗ	ChZ	Fuze, Clockwork, Time
МВЧ	MVCh	Fuze, Clockwork, Mine Fuze
УВ	UV	Fuze, Pull (tension)
МВШ	MVSh	Fuze, Tilt-Rod, Mine Fuze

(*Continued*)

(Continued)

Cyrillic	English	Meaning
МВМ	MVM	Fuze, Pressure, Mine Fuze (improved)
ОЗМ	OZM	Mine, Fragmentation
ТМД-Б	TMD-B	Mine, Anti-Tank, Wood Body (newer design)
ЯМ	YaM	Mine, Anti-Tank, Wood Body (old design)
ТМК	TMK	Mine, Anti-Tank, with Shaped charge
ПМД	PMD	Mine, Anti-Personnel, Wood Body
ПОМЗ	POMZ	Mine, Anti-Personnel, Frag
ПМН	PMN	Mine, Anti-Personnel, Tread Operated
ТМБ	TMB	Mine, Anti-Tank, Pressed Paper Body
ТМ	TM	Mine, Anti-Tank
МВН	MVN	Mine Fuze Magnetic Influence
ТМН	TMN	Mine, Anti-Tank, with Anti-Handling Fuze
МОН	MON	Mine, Directional Frag (claymore)
	Suffixes	
А	A	Cast Iron
Б	B	Improved Projectile—AP
Д	D	Improved Projectile—AP
ДУ	DU	Improved Projectile—Frag
Ж	Zh	Sintered Iron Rotating Band
К	K	Improved Projectile—AP
М	M	Copper Liner (shaped charge)
Н	N	Improved Projectile—Frag
П	P	Improved HVAP Projectile
ПК	PK	Improved HVAP Projectile
С	S	Improved HEAT Projectile
СП	SP	Improved AP Projectile
У	U	Improved AP Projectile
УМ	UM	Improved HEAT Projectile

Soviet Propellant Symbols

Russian	Meaning
ПГ	Flash reducing propellant
ПЕР	Old propellant that has been reworked
СВ	Propellant made from new nitrocellulose
СА	Propellant made from new nitrocellulose for small arms
СФ	Single base spherical small arms propellant
СМ	Propellant made from different lots
СТ	Old propellant revived by adding stabilizing agent

(*Continued*)

(Continued)

Russian	Meaning
ТР	Tubular propellant (symbol precedes first fraction in the propellant data line)
УФ	Propellant produced in shortened manufacturing process, unstable in long storage (symbol found in the propellant data line)
ФМ	Phlegmatized propellant
Х	Propellant for blank ammunition
ГКН	Indicates a smokeless, flashless, nonhygroscopic propellant
ШМ	Fine-grained cord nitrocellulose-methyl centralite propellant, comparable to British 'WM'

Soviet Projectile Weight Classifications

Symbol	Meaning
ЛГ	Greater than 3% below standard
----	2.33% to 3% below standard
---	1.66% to 2.33% below standard
--	1% to 1.66% below standard
-	0.33% to 1% below standard
Н	0.33% below to 0.33% above standard
+	0.33% to 1% above standard
++	1% to 1.66% above standard
+++	1.66% to 2.33% above standard
++++	2.33% to 3% above standard
ТЖ	Greater than 3% above standard

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Appendix G: Black Powder, Smooth Bore Projectile Diameters and Weights

Designation, Pounder (Pdr)	Diameter, Inches & Millimeter Inch (mm)	Weight, Pounds & Kilograms (Shot)	Weight, Pounds & Kilograms (Shell)	Weight, Pounds & Kilograms (Case Shot or Shrapnel)
1-Pdr.	1.95 (49.53)	1 (.45 kg)		
3-Pdr.	2.84 (72.13)	3.05 (1.38 kg)		
4-Pdr.	3.12 (79.24)	4.07 (1.85 kg)		
6-Pdr.	3.58 (90.93)	6.1 (2.77 kg)		3.22 (1.46 kg)
9-Pdr.	4.10 (104.14)	9.14 (4.4 kg)		
12-Pdr.	4.52 (114.80)	12.25 (5.55 kg)	8.34 (3.78 kg)	6.22 (2.82 kg)
18-Pdr.	5.17 (131.31)	18.3 (8.3 kg)	13.45 (6.1 kg)	9.27 (4.2 kg)
24-Pdr.	5.68 (144.27)	24.3 (11 kg)	16.8 (7.62 kg)	12.32 (5.59 kg)
32-Pdr.	6.25 (158.75)	32.4 (14.7 kg)	22.5 (10.2 kg)	16.12 (7.3 kg)
42-Pdr.	6.84 (173.73)	42.5 (19.28 kg)	31.3 (14.2 kg)	20.73 (9.4 kg)
8-inch	7.88 (200.15)	65 (29.5 kg)	44.12 (Mortar) (20 kg) 49.75 (Gun) (22.56 kg)	30.36 (13.77 kg)
9-inch	8.85 (224.79)	88 (39.9 kg)	70 (31.75 kg)	
10-inch	9.87 (250.69)	127.5(57.83 kg)	88.42 (Mortar) (40.1 kg) 101.67 (Gun) (46.1 kg)	
11-inch	10.87 (275.59)	165 (74.84 kg)	132 (59.88 kg)	
12-inch	11.87 (301.49)	222 (100.7 kg)		
13-inch	12.87 (326.89)	282.84 (128.3 kg)	197.3 (Mortar) Model 1841 (89.5 kg)	
15-inch	14.85 (377.19)	440 (199.6 kg)	352 (159.66 kg)	

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